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CHARLES F. MARVIN, Chief

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological and seismological contributions and bibliography; (2) an interpretative summary and charts of the weather of the month in the United States and adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) results of observational or research work in meteorology carried on in the United States or other parts of the world,—in the Weather Bureau, at universities, at research institutes, or by individuals; and (*b*) abstracts or reviews of important meteorological papers and books. In each issue of the REVIEW such contributions and abstracts are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather, applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library, U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Havana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

Supplements containing kite observations, and others containing monographs are published from time to time.

SOME WEATHER BUREAU PUBLICATIONS.

A few of the more recent Weather Bureau publications are listed below, with their prices. A complete list may be obtained upon application to the *Chief, U. S. Weather Bureau.*

To secure such publications as have a price affixed, one should apply to and make remittances payable to the *Superintendent of Documents, Government Printing Office, Washington, D. C.* Stamps and personal checks are not accepted in payment. There is an additional charge for postage for foreign addresses.

National Weather and Crop Bulletin, with charts, monthly from October to March, weekly during remainder of the year	25c. year.
Snow and Ice Bulletin, with charts, weekly during the winter	25c. season.
Climatological data, monthly for 42 separate sections, each section 5c, a copy	50c. a year.
Complete monthly number, 42 sections	35c. each, $4.00 year.
Periodical events and natural law as guides to agricultural research and practice (Monthly Weather Review Supplement No. 9.)	25c.
Monthly Weather Review Supplements Nos. 10 and 11. (Aerology Nos. 5 and 6), 1917 kite data	25c. each.
Monthly Weather Review Supplement Nos. 12, 13 and 14. (Aerology Nos. 7, 8 and 9), 1918 kite data, etc	25c. each.
Weather forecasting in the United States	$1.25
The daily weather map, with explanation (text and 4 charts)	5c.
Instructions for cooperative observers, 5th ed. Circulars B and C combined	10c.
Instructions for the installation and operation of Class A evaporation stations. Circular L	10c.
Report of the Chief of the Weather Bureau, 1917–1918 (4° edition)	Free.
Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Notes on the climate of France and Belgium	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
Explanation of the weather map (leaflet)	Free.
Serial numbers of Weather Bureau publications	Free.
Papers on meteorology as a subject for study. (Repr. from Dec., 1918, Mo. Wea. Rev.)	10c.

As the surplus of MONTHLY WEATHER REVIEW SUPPLEMENT No. 2 is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

MONTHLY WEATHER REVIEW

HERBERT H. KIMBALL, Acting Editor.
CHARLES F. BROOKS, Associate Editor.

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CONTRIBUTIONS AND BIBLIOGRAPHY.

WORK OF THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY AT CALAMA, CHILE.

By C. G. ABBOT, D. Sc., Assistant Secretary, Smithsonian Institution.

[Dated: Washington, Feb. 17, 1919.]

Since the year 1902, the Smithsonian Astrophysical Observatory has been conducting observations to determine the solar constant of radiation. Early in the work it appeared that the solar radiation is not constant but variable in short irregular intervals of a few days or a few weeks, and later it appeared that the sun varies also in average output of radiation from year to year. The longer period variations seem to be associated with sunspot and other visible solar activities, and the shorter-period irregular fluctuations we have found to be associated with changes of distribution of brightness along the diameter of the solar image. We incline to assign the causes of these observed variations as follows:

When the sun is in great activity, as shown by sunspots, prominences, and the like, it is like poking a fire and bringing fresh coals to the surface. Thus, we look at such times on a hotter sun, and naturally we obtain greater values of the solar constant of radiation corresponding. This view is confirmed by the studies of the changes of distribution of radiation over the sun's diameter, for if the temperature of the sun were zero there would be no contrast of brightness whatever along the diameter, and the higher the temperature the greater becomes the contrast. We have found, correspondingly to this, more contrast between the brightness of the center and edges of the sun at times when the solar activity was high.

The shorter irregular fluctuations of solar radiation we have explained by changes in the transparency of the outer solar envelopes. This view is supported by the solar contrast work, for we find that high values of the solar radiation, as they fluctuate to and fro in their irregular intervals of time, correspond to low values of contrast between the center and edge of the sun.

It will be clear to the reader that if the sun's outer envelopes become more transparent, the result would be to increase the radiation at all points of the sun's disk, but the increase would be greatest at the solar limb, where the thickness of the outer envelopes as seen obliquely is greatest. Thus *increased* radiation and *decreased* contrast of brightness will go hand in hand for variations due to changes in the transparency of the solar envelopes.

Since the sun is the support of the earth's temperature, and the cause of the circulation of the atmosphere, as well as the disturber of terrestrial magnetism, it is to be expected that variations in the solar activity would be associated with terrestrial changes. This has been found to be the case. For many years the close correspondence between sunspot activity and terrestrial magnetism has been known.

More recently Dr. Bauer has found a correlation between the short irregular fluctuations of solar radiation observed by the Smithsonian Astrophysical Observatory and certain outstanding changes of terrestrial magnetism. Various meteorologists, especially W. Köppen, have shown by their investigations that the temperature of the earth fluctuates with sunspot activity and is on the whole higher at sunspot minimum than at sunspot maximum. Helland-Hansen and Nansen draw attention to the fact that fluctuations in terrestrial temperature seem to have more frequent periodicity than fluctuations in sunspot activity. They draw attention also to the corresponding phenomenon in solar prominences and incline to think that the activity of the sun has a period of the order of three years which is reflected in the terrestrial temperatures.

Recently Dr. H. H. Clayton has determined the correlation between the short-period variations of the solar radiation as measured by the Smithsonian Institution at Mount Wilson, and the temperatures of some 50 stations distributed over the world. He finds some indications of correlation between the two variables, and that positive correlations generally occur in tropical regions, negative ones in temperate regions, and positive ones again in polar regions. At some stations the correlation is very strong, at others very weak. Dr. Nansen has studied these correlations for the Scandinavian Peninsula, and informs me privately that there is a fairly close and large factor of correlation there. He, however, is of the opinion that when sufficient data are correlated it will be found that areas of positive and negative correlation between short period solar changes and terrestrial temperatures will be associated with the great action centers of the atmosphere, rather than zonally, as supposed by Clayton.

In all investigations of the dependence of terrestrial temperatures on solar activity, it is apt to be found that the values go along together with a certain kind of dependence for a long course of years and then shift about and either show no dependence or else an opposite relation to what prevailed before. This is very confusing in statistical investigations of the kind, and has left so accomplished an investigator as Newcomb with a view that there is no variation of the sun, and no fluctuation of the earth's temperature dependent upon it except the slight one associated with the sunspot period.

The reason for this puzzling phenomenon of secular change of sign in temperature correlations may be that since the atmosphere absorbs a large portion of the sun's radiation, and since the capacity for heat of the atmosphere is very small, and since the configuration of the earth with its oceans, its mountains, its deserts, and the like, makes the relations between solar heat and terrestrial temperature very complex, a fluctuation of

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the solar radiation may easily cause a change in the distribution of atmospheric circulation, and thus a change in the direction of the wind prevailing at any given station. It is a matter of common observation that when we have southerly winds we generally have warm temperatures, and when northerly winds cold temperatures. If then a change in position of the great action centers of atmosphere presents a period of warm winds from the south, where cold ones from the north formerly prevailed, there will be corresponding general increase in the temperature of such a region, and this may happen notwithstanding that at the same time a decrease in the solar radiation has occurred which, while it primarily would tend to diminish temperatures secondarily, acts more powerfully in the contrary sense.

It is obviously essential to the proper study of these perplexing and important phenomena that sufficiently accurate measurements of the solar radiation should be available to follow the changes of solar output daily for a long course of years. When such a series of observations is available the dependence of terrestrial temperatures upon solar changes will probably be capable of elucidation. Hitherto the measurements made by the Smithsonian Institution at Washington, Mount Wilson, Mount Whitney, Bassour, Algeria, and Hump Mountain, N. C., have been too fragmentary, owing to cloudiness and other conditions, to give a satisfactory basis for such a study. About a year ago, however, the Institution sent an expedition to Calama, Chile, for the purpose of measuring the solar constant of radiation day after day for a term of years. The station lies at the eastern edge of the nitrate desert, about 150 miles northeast of Antofagasta, on the River Loa and on the railroad leading from Antofagasta to Bolivia. The expedition is in charge of Mr. A. F. Moore, director, with Mr. L. H. Abbot, assistant.

The location chosen at Calama is an abandoned mining property of the Chile Exploration Co., which they very generously put at our disposal for this purpose. The expedition took station in June, 1918, and began observing regularly on July 27, 1918. On last accounts, January 12, 1919, the solar constant of radiation had been observed on 123 days out of a possible 170 days. In the month of December an unusually large number of days was lost on account of cloudiness, and it is not improbable that similar conditions may prevail in January and February, when the rainy season occurs in Bolivia. Unpublished meteorological observations kindly furnished by Dr. Walter Knoche, formerly director of the meteorological service of Chile, indicated a somewhat larger proportion of favorable days than has been found, but we incline to the view that the present period is disturbed from the normal all over the world, and that perhaps in the course of a year or two better conditions may be found.

The values of solar radiation thus far observed have been generally high, practically every one above 1.90, and they average above 1.95 calories per square centimeter per minute. This would perhaps be expected in view of the large number of sunspots still prevailing, although we have passed the maximum of the present sunspot period.

A few words in regard to the kind of apparatus employed may be of interest. Outside the observing shelter is a coelostet of two mirrors with clockwork rotating the polar axis, on which one of the mirrors rests at the rate of one revolution in 48 hours. The second mirror sends the solar beam horizontally southward into the observing shelter, where it falls upon a vertical slit about 8 cm. high and 0.4 mm. wide. The light from the slit passes on about 3 m. to a 60° prism of ultra-violet crown glass, which prism is traversed by the rays in minimum deviation, and the emergent beam is reflected by a plane mirror, which lies parallel with the back of the prism onwards toward a concave image-forming mirror about 1 m. farther to the south. This mirror focuses the spectrum upon the sensitive strip of a vacuum bolometer at about 1 m. distant from it.

The vacuum bolometer, designed for the highest possible sensitivity, is entirely inclosed within a sealed glass vessel which is inclosed in a suitable case of metal having a diaphragmed vestibule for the entrance of the spectrum, and an eyepiece to observe the focus upon the bolometer strip. The warming and cooling of the exposed strip of the bolometer is detected by means of a highly sensitive Thomson reflecting galvanometer, which measures the amount of unbalancement in the Wheatstone's bridge, of which the bolometer strips are a part, due to the differential rise of temperature of the exposed bolometer strip over its neighbor, which is hidden from the spectrum by a diaghragm. Changes of the temperature of the exposed bolometer strip as small as one one-millionth of a degree Centigrade are recognizable upon the scale of the galvanometer, and are autographically reproduced on a photographic plate which moves vertically in front of the galvanometer in a box behind a horizontal slit.

The movement of the photographic plate is governed by clockwork, and the same clockwork moves the spectrum along over the exposed strip of the bolometer. Thus the horizontal deflections of the galvanometer are drawn out upon the photographic plate into a sinuous line, whose high peaks represent warm parts of the spectrum and whose low valleys represent cool parts of the spectrum.[1] The whole length of the solar spectrum from 0.34 microns to 2.8 microns is autographically reproduced as an energy curve in about seven minutes by this apparatus.

In order to prevent the curve from going off of the photographic plate at the most intense regions of the spectrum, we employ a series of three rotating sectors which may be introduced before the slit of the spectroscope and which cut down the intensity in the proportions one-third, one-ninth, and one-thirtieth, approximately.

Six such spectro-bolometric energy curves of the solar spectrum are made on each observing day between the hours when the sun is low and the sun is high.

The range of air masses corresponding to the measurements is usually taken from about 5 to about 1.2 times that which would prevail if the sun were vertically overhead. This requires a time interval of approximately three hours for the observations, and it is an unsatisfactory feature of the method that so long a time must elapse in order to determine the transparency of the atmosphere. For it is possible for the approach of changes in meteorological conditions in the upper atmosphere to produce a gradual clearing or increasing turbidity of the air, and these tend to produce too high or too low values of the solar constant of radiation, respectively. We are attempting to develop instantaneous methods for estimating atmospheric transparency. If successful they will largely increase the number of satisfactory determinations.

As the bolometer is not in itself a standard instrument, we are obliged to determine the scale of intensities which it represents. In order to do this, we note that the area included under the spectro-bolometric curve, when the

[1] See this REVIEW, May, 1902, Plate 1, XXX-50, for reproductions of bolograms.—ED.

curve has been corrected for losses in the apparatus, must be proportional to the total heating effect of all the sun's rays combined, as these might be observed with the pyrheliometer. Accordingly, in standardizing the bolometric work we read the pyrheliometer at the time when each of the six curves is made, and by dividing the reading of the pyrheliometer by the area of the corresponding bolographic curve a constant is obtained from which the sensitiveness of the bolometer is determined. This constant is applicable not only to the curves as they actually stand at the earth's surface, but also to the curve outside the atmosphere as corrected for atmospheric transmission, as the latter is determined by the dependence of the intensities at different wave lengths on the thickness of the atmosphere traversed.

We employ to measure the total heat of the sun the standardized silver disk pyrheliometer, of which the institution has furnished about 30 copies to various governmental and private institutions in different parts of the world. Two copies of this instrument are employed at Calama. They are mounted upon the same equatorial stand, and the observer reads them successively, so that during the taking of each spectro-bolometric curve he gets the reading of the two pyrheliometers.

The air mass corresponding to the observation is determined by means of a theodolite which gives the zenith distance of the sun. A table has been prepared giving the air mass corrected according to Bemporad, corresponding to the zenith distance observed. This procedure saves the determinations of time and the computation of the air mass in the manner still employed at Mount Wilson.

In reducing the observations of the spectro-bolometer, we measure the heights of the six successive curves at about 40 points, corresponding to the different wave lengths in the spectrum. The determination of the corresponding intensities in the solar spectrum outside the atmosphere we determine by a graphical method instead of the logarithmic computations which we have hitherto used in Washington.

For the purpose of this graphical extrapolation we have constructed a special slide-rule machine. An accurate steel frame with a horizontal scale of distances in centimeters has upon it six slide rules whose positions may be adjusted along the horizontal scale according to the air mass at which observations were made. We then set off upon the sliders vertically the observed intensities of solar radiations at a single wave length as read from the six curves. As these values are logarithmically plotted in the slide rule they fall upon a straight line, which produced to the abscissa of zero air mass gives the intensity which would be found outside the atmosphere, as on the moon for example. The numerical value is read off on a seventh slide rule situated at the zero of air mass.

In order to make extrapolation easier, a taut wire attached to the slider of the rule located at zero air mass and to a slidable reel at the other extremity of the steel frame is adjusted until it falls as closely as possible upon the six points determined by the six slide rules. In this way quick and accurate extrapolations of the data to the zero of air mass may be made.

The observers are so skillful and zealous in the reduction of the observations that, thanks also to these special devices, they are able to complete the determination of the solar constant of radiation on the same day that the observations are made, although in our former practice at Washington the computation required amounted to 25 hours. Thus it is possible for two observers to determine in a single day the solar constant of radiation so as to be in a position to telegraph the result, if it was desirable, within 10 hours of the beginning of the observations. However, so grinding an occupation as the observation and computation of solar constant values day after day would soon wear out so small a staff, and we expect in the immediate future to add another person to it.

Messrs. Moore and Abbot are in communication with Dr. H. H. Clayton, of the meterological service of Argentina, who is making studies of the relations of temperature of Argentina to the solar constant values they determine. Dr. Clayton speaks very enthusiastically of the apparent connection of the two variables and even mentions that correlations as high as 68 per cent are being found between them.

If this state of affairs should be confirmed, if it is found in future that the temperature of any station upon the earth's surface may be predicted for some time in advance on the basis of the values of the solar constant of radiation, it will seem to be indicated that a sufficient number of solar radiation stations should be established to observe not merely 70 per cent of the days, but all days, for the use of meteorologists. For such a purpose three or four more stations ought to be equipped in the most widely separated cloudless regions of the earth—let us say Australia, South Africa, India, and Egypt. While it would no doubt be advantageous if all these stations could be under a single management, as, for instance, that of the Smithsonian Institution, yet the institution has not at present the means available for the establishment and continuation of them. About $50,000 for the establishment and $50,000 annually for maintenance would be needed. Very probably it might be easier to secure the necessary funds if the various governments of the regions indicated should themselves establish and support their observing stations. Possibly no defect of homogeneousness in the results would arise from such a divided control. At all events the matter of the establishment of additional stations may well be delayed for at least a year, until the results of Dr. Clayton on the correlation of solar radiation with terrestrial temperatures shall be further advanced.

TERRESTRIAL WEATHER AND SOLAR ACTIVITIES.

By Charles F. Marvin, Chief of Weather Bureau.

[Dated: Washington, Feb. 21, 1919.]

Meteorologists have long been accustomed to ascribe practically all atmospheric motions, both local and general, to the gravitational flow resulting from the local and general contrasts of temperature over the surface of the earth. The atmosphere derives its heat, not directly from the sun, except to a small extent, but chiefly from the surface of the earth itself. The daily sequence of sunshine and darkness; the varied distribution of clear and cloudy skies; diversities of surface cover added to contrasts of land and water areas, including the phenomena of evaporation, condensation, and precipitation; the cycle of the seasons, and above all the fluctuating but nevertheless perpetual contrasts of surface temperatures, ranging all the way from the heat of the Tropics to the intense cold of the polar zones constitute a complex series of varied and changeable influences seemingly abundantly adequate to cause and explain every feature of our weather conditions, however changeable we may find them.

These differences and contrasts on the one hand perpetually disturb the orderly arrangement of air densities

and pressures demanded by gravity. The latter, on the other hand, as perpetually and continuously sets portions of the air in motion, in order to establish and maintain a state of equilibrium, which, however, is never attained, or rather we must clearly recognize that *the ceaseless complex changes in and motions of our atmosphere represent in fact the only state of equilibrium possible between gravity on the one hand and solar heating of the earth on the other.*

Seemingly with little regard for the considerations just mentioned, many have sought and still seek to ascribe terrestrial weather—that is to say, *all* the characteristic features of atmospheric variations—to *minor* features of solar activity, as, for example, to the spots and faculae of the sun or to its magnetic manifestations, or to the relatively small and irregular fluctuations in the intensity of its thermal radiations, or to some of these variously in combination, etc.

Even suppose these solar phenomena directly influence terrestrial weather in some way yet to be proved, is it not plainly most essential in detecting and analyzing cause and effect relations that we adequately segregate and make due allowance for the complex phenomena which clearly must result if solar insolation were perfectly constant and if the other manifestations of solar activity were entirely absent?

Those who have been most ready to find convincing evidence of definite relations between terrestrial weather and minor features of solar activity have seemingly disregarded the obligation devolving upon them to make the segregation, we have mentioned as necessary, between the major and the minor influences, or have tacitly inferred that such a result has been automatically attained merely as an indirect consequence of involved processes of combinations and analyses of data, quite, however, inadequate in themselves.

Variations in the intensity of thermal radiations from the sun must, of course, be reflected in terrestrial weather phenomena, but such reflected effects must stand in appropriate relation quantitatively to the variations themselves. The advocates of definite relations are generally too prone to follow a line of thought which, pushed to an issue, leads to the conclusion that "variations of terrestrial weather," "deviations from the average," or whatever unit or term may be employed to express weather features, are ascribable directly to solar variations. The fallacy or doubt of the correctness of such a view is brought out if we ask, would the "deviations," "variations," "departures," etc., be *nil* or nonexistent if the intensity of solar radiation were perfectly constant? We think this question can be answered only in the negative, which is very largely at least a refutation of many of the conclusions thus far advocated, or at least questions the quantitative correctness of such results.

Meteorologists must hail with approval the action of the astrophysical observatory of the Smithsonian Institution in establishing a permanent station for continuous observations of solar radiation at Calama, Chile, in South America, the objects and equipment of which are so well described by the director of the observatory, Dr. Charles G. Abbot, in the preceding note in the REVIEW. The collection of a prolonged series of nearly continuous measurements of solar radiation intensities, even from a single observatory, will supply meteorologists with much needed material for refining their studies of close relations between terrestrial weather and solar activity. It is greatly to be hoped that a few other like observatories may be established at distant points over the earth in order to bridge the inevitable gaps in the series of observations and to confirm and verify the general correctness of the results obtainable at a single station.

SOLAR AND SKY RADIATION MEASUREMENTS.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Weather Bureau, Washington, Mar. 1, 1919.]

INSTRUMENTS AND EXPOSURES.

In the REVIEW for January, 1916, **44**:2, will be found descriptions of the exposures of the Marvin pyrheliometer at the various stations and an account of the methods of obtaining and reducing the radiation measurements. These still apply, except as amended in the REVIEW for January, 1917, **45**:2. The increased amount of local smoke in the atmosphere at the American University, Washington, D. C., referred to in the REVIEW for January, 1918, **46**:2, was eliminated with the discontinuance of the activities of the experiment station of the Chemical Warfare Service at the end of 1918.

On May 21 and June 14, 1918, respectively, the Marvin pyrheliometers of the spiral ribbon type in use at Lincoln, Nebr., and Madison, Wis., were replaced by Marvin silver block pyrheliometers. The factors for reducing the readings of these latter instruments to heat units were determined by comparison with simultaneous readings of Smithsonian silver disk pyrheliometer No. 1, the factors of the Marvin instruments having been first approximately determined by the electrical heating process described by Foote.[1]

In the REVIEW for January and April, 1916, **44**:4, 179–180, will be found descriptions of the exposures of the Callendar recording pyrheliometer at the different stations and an account of the method by which these records are reduced to heat units. These still apply, except as modified in the REVIEW for January, 1917, **45**:2.

The statements in the REVIEW for January, 1916 and 1917, **44**:2 and **45**:2, relative to skylight polarization measurements, and in the REVIEW for January, 1917, **45**:2, relative to radiation normals and the extrapolation of pyrheliometric readings to air mass 1, also still apply.

OBSERVATIONS DURING JANUARY, 1919.

Table 1 is a summary of the measurements made at the different stations with the Marvin pyrheliometer. The departures from normal values indicate that direct solar radiation intensities were very close to normal at Madison, slightly below normal at Lincoln, and slightly above at Washington. A noon reading of 1.42 calories obtained at Washington on the 27th equals the highest January reading heretofore obtained at Washington.

No measurements were obtained at Santa Fe, N. Mex., on account of a defect in the galvanometer.

Table 3 shows close to normal radiation for the month at Washington, a deficiency at Madison during the second and third decades, and an excess at Lincoln during the first and second decades.

Skylight polarization measurements at Washington on five days give a mean of 55 per cent, with a maximum of 60 per cent on the 27th. These are below the average values for Washington. At Madison measurements on the last three days of the month, when the ground was bare of snow but ice covered Lake Mendota, give a mean of 58 per cent, with a maximum of 70 per cent on the 30th.

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[1] See abstract in this REVIEW for November, 1918, **46**: 499–500.

TABLE 1.—*Solar radiation intensities during January, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Jan. 4	(*1.41)		1.20	1.10	1.01	0.92	0.85	0.77		
6			1.16	1.09	0.99	0.97	0.92	0.87	0.84	0.80
7	(*1.39)			1.06	0.96	0.87	0.80	0.73	0.68	
10			1.34	1.28						
13			1.19	1.00						
16	(*1.35)			1.24	1.16	1.08	0.99	0.92	0.91	0.82
25								0.86	0.78	
27			1.35	1.22	1.09	1.01	0.94	0.88	0.81	
28					0.96	0.89				
29						0.85	0.75			
30	(*1.43)		1.24	1.16	1.07	1.00	0.91	0.85	0.80	0.74
31			1.32	1.22	1.15	1.09	1.03	0.98		
Monthly means			**1.26**	**1.15**	**1.05**	**0.96**	**0.90**	**0.86**	**0.80**	**0.79**
Departures from 11-year normal			**+0.04**	**+0.05**	**+0.04**	**+0.02**	**+0.03**	**+0.05**	**+0.05**	**+0.08**
P. M.										
Jan. 4				1.16	1.05	0.96	0.87	0.79		
8			1.17	1.09	1.00	0.96	0.88	0.82	0.76	
13				1.09	1.01	0.94	0.80			
27				1.27	1.12	1.03	0.94	0.85		
30			1.19	1.06	0.97	0.89	0.81	0.74	0.68	
31			1.28	1.19	0.98	0.93	0.88	0.83	0.79	0.75
Monthly means			**1.21**	**1.14**	**1.02**	**0.95**	**0.86**	**0.81**	**0.74**	**(0.75)**
Departures from 11-year normal			**−0.02**	**+0.02**	**−0.02**	**±0.00**	**−0.02**	**−0.01**	**−0.03**	**+0.01**

* Extrapolated, and reduced to mean solar distance.

Madison, Wisconsin.

Date.	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.										
Jan. 2					1.33				0.97	0.88
4					1.07					
9				1.46	1.35	1.29	1.25	1.21	1.17	1.13
16				1.29	1.18	1.09			0.89	
28				1.33	1.25	1.17				
29			1.38	1.25						0.77
30			1.43	1.38						
31	(*1.51)		1.38		1.24	1.16	1.08	1.01	0.94	0.89
Monthly means			**1.40**	**1.34**	**1.24**	**1.18**	**(1.16)**	**(1.11)**	**0.99**	**0.92**
Departures from 9-year normal			**+0.04**	**−0.01**	**−0.02**	**+0.01**	**+0.07**	**+0.10**	**+0.05**	**−0.02**
P. M.										
Jan. 9				1.47						
25				1.25	1.20	1.18				
28				1.31	1.27	1.11				
29				1.31	1.11					
31				1.30	1.26					
Monthly means				**1.33**	**1.21**	**(1.14)**				
Departure from 9-year normal				**+0.02**	**−0.02**	**−0.05**				

* Extrapolated, and reduced to mean solar distance.

Lincoln, Nebraska.

Date.	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.										
Jan. 1	(*1.57)			1.35	1.26	1.19	1.11			
2				1.40	1.32	1.27	1.20	1.17	1.13	1.08
3	(*1.53)			1.42	1.37	1.31	1.26	1.21	1.13	
6				1.20	1.05	0.99	0.88	0.83	0.80	
9				1.35	1.20	1.04				
10				1.33	1.13					
14				1.28	1.05					
15	(*1.54)			1.28	1.15	1.05	0.99	0.93	0.87	
29			1.37	1.28	0.96	0.92	0.88			
30			1.14		1.05					
31			1.28	1.19	1.15	1.06				
Monthly means			**1.26**	**1.31**	**1.15**	**1.10**	**1.05**	**1.04**	**0.98**	**(1.08)**
Departures from 4-year normal			**−0.11**	**+0.01**	**−0.03**	**−0.02**	**−0.02**	**+0.03**	**+0.02**	**+0.11**
P. M.										
Jan. 1				1.36	1.17	1.14	1.17	1.12		
6				1.25						
10	(*1.54)			1.34	1.27	1.21	1.15			
14	(*1.46)			1.28	1.22	1.16	1.10	1.04	0.99	0.94
15				1.29	1.22	1.12		1.01	0.96	
29				1.27						
30						0.99	0.92		0.77	
31			1.27	1.12	1.04	0.96	0.88		0.76	
Monthly means			**(1.27)**	**1.27**	**1.18**	**1.10**	**1.04**	**1.06**	**0.87**	**(0.94)**
Departures from 4-year normal				**−0.04**	**−0.05**	**−0.07**	**−0.06**	**±0.00**	**−0.13**	**−0.07**

* Extrapolated, and reduced to mean solar distance.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.		
Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.
1919.	mm.	mm.	1919.	mm.	mm.	1919.	mm.	mm.
Jan. 4	0.91	0.96	Jan. 2	0.79	0.48	Jan. 1	0.64	1.07
6	1.96	2.26	4	0.28	0.71	2	0.91	0.46
7	2.36	3.15	9	1.52	1.07	3	0.33	0.79
8	4.17	3.63	16	3.15	3.99	6	2.36	4.37
10	1.32	1.78	25	4.57	3.15	9	2.87	3.99
13	2.11	4.17	28	2.36	1.60	10	2.87	4.75
16	3.00	3.63	29	1.78	3.45	14	2.62	3.81
25	3.99	4.17	30	2.49	1.78	15	3.00	4.17
27	2.62	3.30	31	1.60	1.45	29	3.00	4.75
28	3.99	3.45				30	2.36	3.99
29	2.06	2.49				31	2.49	5.16
30	2.49	3.63						
31	2.06	2.06						

TABLE 3.—*Daily totals and departures of solar and sky radiation during January, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Jan. 1	24	126	285	−136	− 15	99	−136	− 15	99
2	16	204	267	−145	62	79	−281	47	178
3	137	186	269	− 24	43	79	−305	90	257
4	240	170	145	78	25	− 47	−227	115	210
5	189	107	223	27	− 39	29	−200	76	239
6	228	140	256	65	− 8	60	−135	68	299
7	216	106	218	52	− 43	19	− 83	25	318
8	126	157	271	− 38	6	70	−121	31	388
9	135	213	252	− 30	61	49	−151	92	437
10	240	164	273	74	10	67	− 77	102	504
11	232	96	240	66	− 50	32	− 11	43	536
12	250	123	205	83	− 34	− 5	72	9	531
13	235	156	179	67	− 2	− 33	139	7	498
14	130	158	279	− 39	− 2	64	100	5	562
15	111	222	290	− 59	60	73	41	65	635
16	253	204	282	81	39	62	122	104	697
17	78	142	199	− 96	− 27	− 24	26	77	673
18	118	140	243	− 58	− 32	18	− 32	45	691
19	198	52	305	19	−124	77	− 13	− 79	768
20	209	77	79	28	−102	−152	15	−181	616
Decade departure							**92**	**−283**	**112**
21	217	100	50	34	− 83	−184	49	−264	432
22	70	37	70	−116	−149	−167	− 67	−413	265
23	31	108	212	−157	− 82	− 27	−224	−495	238
24	258	155	243	68	− 38	1	−156	−533	239
25	225	196	309	32	0	64	−124	−533	303
26	174	224	288	− 21	26	41	−145	−507	344
27	298	172	268	101	− 28	18	− 44	−535	362
28	185	230	284	− 15	28	31	− 59	−507	393
29	210	235	312	8	31	56	− 51	−476	449
30	300	242	316	96	36	57	45	−440	506
31	335	236	324	128	28	62	173	−412	568
Decade departure							**158**	**−231**	**−48**
Excess or deficiency since first of year, gr.-cal							**173**	**−412**	**568**
Excess or deficiency since first of year, per cent							**3.1**	**−7.8**	**8.3**

INFLUENCE OF THE SOLAR ECLIPSE OF JUNE 8, 1918, UPON RADIATION AND OTHER METEOROLOGICAL ELEMENTS.

By HERBERT H. KIMBALL, Professor of Meteorology, and S. P. FERGUSSON, Meteorologist.

[Dated: Weather Bureau, Washington, Mar. 4, 1919.]

INTRODUCTION.

The Weather Bureau program in connection with the solar eclipse of June 8, 1918, included measurements of both incoming and outgoing heat radiation at a station established for that purpose at Goldendale, Wash., observations of shadow bands at stations in or near the path of total solar obscuration, and observations of the usual meteorological elements at about 55 Weather Bureau stations within the zone of 90 per cent obscuration. While the preliminary arrangements were jointly

in the hands of the authors of this paper, Prof. Kimball more particularly concerned himself with the radiation measurements, and Mr. Fergusson with the shadow-band and meteorological observations. A similar subdivision of the work has been followed in the preparation of this paper, except that most of the pressure, temperature, and shadow-band observations have been reduced and tabulated by Prof. Kimball or under his direction.

RADIATION MEASUREMENTS.

These measurements were made by Prof. Kimball at Goldendale, Wash., lat. 45° 49′ N., long. 120° 50′ W., elevation above sea level 1,650 feet (503 meters). This location was selected for the following reasons:

(*a*) The average rainfall for June (11-year record) is only 0.45 inch.

(*b*) Cumulus clouds, so common farther east, are of infrequent occurrence.

(*c*) The total phase of the eclipse occurred with the sun high above the horizon, and near the time of maximum heat for the day. (Center of totality, 2:59 p. m., 120th meridian time.)

(*d*) The duration of totality (1 min. 58 sec.) was greater than at points farther east, and farther west, near the Pacific coast, there was greater probability of cloudiness.

(*e*) Goldendale has a comfortable hotel, and help and material for installing the apparatus were available.

The installation of the apparatus was very simple. A 6 by 6 inch post was set firmly in the ground, and shelves were attached to its south and west faces to support two galvanometers. A box, 4 feet cube, with the entire south side taken up by a hinged door, was built over this post. A pyrgeometer [1] of the Ångström type, made by Dr. W. W. Coblentz, of the Bureau of Standards, and a pyranometer [2] made under the supervision of Dr. C. G. Abbot, director of the astrophysical observatory of the Smithsonian Institution, were exposed upon carefully leveled blocks on top of this box. The pyrgeometer was employed in measuring the outgoing, or so-called nocturnal, radiation, and the pyranometer in measuring both the incoming and the outgoing radiation. On a shelf inside the box were placed a milammeter for measuring the heating current used with the radiation instruments, and a rheostat for controlling the strength of this current, which was obtained from a storage battery of three cells. The observer was able to sit in front of this box, read the galvanometer deflections, regulate the heating current, and expose or shade the radiation apparatus as desired, the latter being just above his head. When not in use the instruments were locked up inside the box.

An instrument shelter containing maximum and minimum thermometers, a thermograph, and a hygrograph was located near the radiation apparatus. These former, and observations with an Assmann and a sling psychrometer, and also eye observations of clouds and wind, were intrusted to Mr. G. N. Salisbury, of the Seattle (Wash.) Weather Bureau office.

The installation of the apparatus was completed about noon of June 4, and observations began at once. They were continued until about noon of June 10. No rain fell during this time, and there were few lower clouds. Unfortunately, the distribution of atmospheric pressure was such as to favor the formation of upper clouds on practically every day. On the day of the eclipse the sky was from six to eight tenths obscured, principally with Ci.St. and A.St. clouds, until about 11 a. m., 120th meridian time,[3] when it became nearly clear. By 12:30 p. m. it had become nearly overcast with A.Cu. and A.St. clouds, which continued into the night, except for a fortunate break just before the total phase of the eclipse, which allowed an excellent view of that phenomenon.

Prof. Campbell (17)[4] has already referred to this spectacular clearing of the sky at Goldendale just at the moment when nearly everyone had abandoned hope of viewing the eclipse. Another spectacular feature is worthy of record. To the northwest of Goldendale the snow-white peak of Mount Adams, 40 miles distant, was distinctly visible, as was also Mount Hood, 50 miles to the southwest. Mount Adams was directly in the path of totality, and disappeared from view when the shadow of the moon passed over it. Many observers watched this shadow cross the valley between Mount Adams and Goldendale. When it reached Goldendale, Mount Hood, which was just to the south of the path of totality, suddenly sprang into prominence as though powerfully illuminated. This was, of course, due to the cutting off of diffuse light from the atmosphere between Goldendale and Mount Hood.

In figure 1 the solid line A is a diurnal curve of the total radiation received on a horizontal surface directly from the sun and diffusely from the sky on clear days. It is based on pyranometer measurements, indicated by crosses, that were made at Goldendale between midday, June 4 and 8 p. m. June 8, 1918. The solid line B represents the diffuse radiation received on a horizontal surface from a clear sky, and is also based upon pyranometer readings, indicated by circles, obtained at Goldendale during the above-mentioned period.

The broken line C represents the total radiation measured by the pyranometer on the afternoon of June 8.[5] Measurements obtained at 10:48 a. m. and 11:58 a. m., with the sun unobscured, fell on curve A. The broken line D represents the diffuse solar radiation measurements made with the pyranometer on June 8. They are considerably higher than those of the clear-sky curve, B, on account of the reflection and diffusion of solar rays by the clouds that were present. At 12:40 p. m., and again at 2:05 p. m., it will be noticed that curves C and D coincide, as the sun was totally obscured by clouds. They also coincide when the eclipse was total.

Curves A and B do not differ greatly from similar curves made at Mount Weather, Va.,[6] with a Callendar recording pyrheliometer, on May 8, 1913, and June 30, 1914, if we take into account the difference in the zenith distance of the sun at noon at the two stations on the respective dates.

The solid curve E is a diurnal temperature curve and is based on thermograph records obtained at Goldendale between midday June 4 and midday June 10, 1918, corrected by comparison with the readings of the maximum and minimum thermometers, and the dry-bulb thermometers of the psychrometers.

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[1] For a description of this instrument and the method by which it was standardized, see the REVIEW for February, 1918, 46:57. Pyrgeometer No. 2 was used at Goldendale.

[2] For a description of this instrument, see Smithsonian Misc. Col., 66, Nos. 7 and 11.

[3] From June 5 to June 9, inclusive, 120th meridian time was two minutes faster than apparent time at Goldendale.

[4] Figures in parentheses ( ) refer to references in the bibliography at the end of this paper.

[5] For a record obtained under similar conditions by means of a Callendar recording pyrheliometer see Callender, H. L., Reports on the total solar eclipse of 1905, Aug. 30, pt. 2. (Proc. Roy. Soc. London. 1906. Ser. A, v. 77, p. 18, fig. 4.)

[6] See figs. 5 and 7, MONTHLY WEATHER REVIEW, August, 1914, 43:477, 481.

The broken line F represents the thermograph curve obtained on June 8, similarly corrected.[7] It is to be noted that between 12:15 p. m. and 1 p. m., with a fall in insolation intensity from 1.38 to 0.50 cal. per minute per sq. cm., the temperature dropped about 1.1° C. at a time of day when it should have been rising slightly. It had reached normal again by the time of first contact, and 10 to 15 minutes after totality had fallen 3.6° C., at a time of day when the temperature should have been nearly stationary. It had nearly reached normal again half an hour after fourth contact. Between first contact and 10 minutes after the ending of totality about 35 per cent of the normal radiation was received.

apparently on the leeward side of Simcoe Mountain. Eleven measurements were obtained on June 8 in less than five minutes, varying in value from 0.160 to 0.164 calory. Readings made 20 seconds before and after these were markedly lower, due to the heating effect of the solar rays. A measurement of this latter at 3:03 p. m. gave an intensity of 0.025 calory. From the intensity of the light during totality, which was about equal to that at the end of civil twilight, we may estimate the diffuse radiation to have been less than 0.0001 calory.[8]

It will be noted that on June 8 values of R are lower than the June 9 values and higher than all the June 4-5

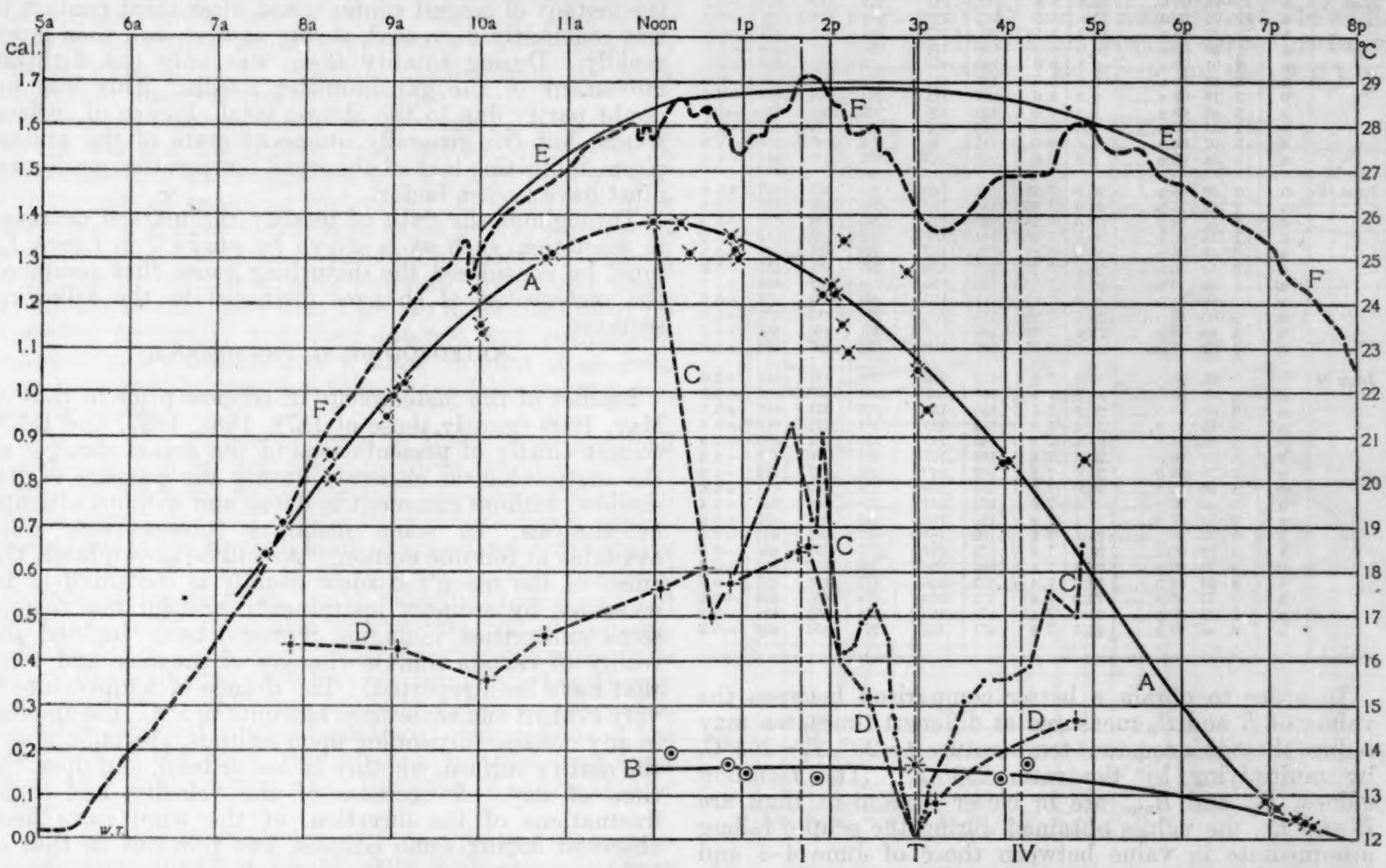

FIG. 1.—Radiation and temperature records at Goldendale, Wash., during the total solar eclipse of June 8, 1918. Curve A—Total radiation from unobscured sun and cloudless sky. Curve B—Radiation from cloudless sky. Curve C—Total radiation measured during the solar eclipse. Curve D—Radiation from the partly overcast sky on June 8. Curve E—Average diurnal temperature curve for the period noon, June 4, to noon, June 10, 1918. Curve F—Temperature on June 8. I, first contact; T, totality; IV, fourth contact.

Between 2:30 p. m. and 3 p. m the fall in temperature was at the rate of 4.0° C. per hour. This exceeds the average rate of cooling at Goldendale from June 4 to June 9, inclusive, 1918, during the hour following sunset, but does not equal the rate of 4.4° C. obtained at this hour on the evening of June 4.

Special interest attaches to the measurements of the outgoing, or the so-called nocturnal radiation, during totality. The mean of the measurements is plotted as a star on figure 1, and it is to be noted that it falls just above the curve of diffuse radiation from a clear sky.

The measurements are also shown in Table 1 in the column headed R, in connection with the measurements obtained on the night of June 4-5, and on the evening of June 9. The latter was cloudless and the former nearly so, except for a stationary St. Cu. cloud,

values except the two first, which were obtained soon after sunset. They are higher than measurements obtained by Aldrich (19) in Kansas later in the afternoon of this same day, and are closely in accord with measurements obtained by Ångström (18) during the solar eclipse of August 20, 1914, except that his were made with a much lower temperature of the surrounding air. If we compute R_a, the radiation from the atmosphere, from the equation $R_a = \sigma T_1^4 - R$, where σ is the radiation constant (8.18×10^{-11} cal. per min. per sq. cm.), and T_1 is the absolute temperature of the instrument, it is seen that R_a was slightly greater on June 8 than on the night of June 4-5 or the evening of the 9th. Likewise, the computed values of t_2, the effective temperature of the radiating atmosphere, is higher during the eclipse than on the other occasions.

[7] This differs somewhat from a temperature curve published by Campbell (17), p. 236.

[8] See also the measurements by Aldrich (19), pages 8-9, Table 1A.

TABLE 1.—*Nocturnal radiation measurements at Goldendale, Wash, June, 1918.*

Date.	Instrument.	Time. (120th merid.).	t.	e.	R.	R_{20}	$R/\sigma T_1^4$	R_a	R_{a20}	t_2
1918.		h. m. s.	°C.	mm.	cal.	cal.		cal.	cal.	°C.
June 4	b	7 57 00 p.....	20.5	6.0	0.176	0.175	0.290	0.431	0.428	−3.6
	a	8 05 00 p.....	20.5	6.0	.168	.167	.277	.439	.436	−2.3
	a	8 25 00 p.....	19.5	6.0	.149	.150	.249	.450	.453	−0.7
	b	8 34 00 p.....	16.0	6.0	.136	.144	.238	.435	.459	−3.0
	b	9 50 00 p.....	15.0	6.0	.132	.141	.234	.431	.462	−3.6
	b	10 01 00 p.....	14.5	5.5	.142	.153	.254	.417	.450	−5.7
	a	10 16 00 p.....	15.5	6.0	.134	.143	.236	.433	.460	−3.3
	a	10 56 00 p.....	14.5	6.0	.129	.139	.231	.430	.464	−4.0
	a	11 02 00 p.....	14.0	6.0	.128	.139	.231	.427	.464	−4.2
	a	11 06 00 p.....	14.0	6.0	.125	.136	.225	.430	.467	−3.7
June 5	a	12 36 00 a.....	10.5	5.5	.118	.135	.223	.410	.468	−5.9
	a	12 40 00 a.....	10.5	5.5	.113	.129	.214	.415	.474	−6.1
	a	1 21 00 a.....	10.5	5.5	.111	.127	.211	.417	.476	−5.8
	a	1 28 00 a.....	10.0	6.0	.108	.124	.206	.417	.479	−5.8
	a	2 01 00 a.....	9.5	6.0	.120	.139	.230	.401	.464	−8.4
	a	2 06 00 a.....	9.5	6.0	.127	.147	.244	.394	.456	−9.6
	b	2 18 00 a.....	9.0	6.0	.121	.141	.234	.396	.462	−9.2
	b	2 48 00 a.....	8.5	6.0	.109	.128	.212	.405	.475	−7.7
	b	2 55 00 a.....	8.5	6.0	.115	.135	.224	.399	.468	−8.7
	a	3 01 00 a.....	8.5	6.0	.111	.130	.216	.403	.473	−7.9
	a	3 06 00 a.....	8.5	6.0	.104	.122	.202	.400	.481	−8.6
June 8	a	2 56 48 p.....	26.0	7.25	.161	.148	.246	.493	.455	+5.6
	a	2 57 15 p.....	26.0	7.25	.160	.148	.245	.494	.455	+5.8
	a	2 57 34 p.....	26.0	7.25	.160	.148	.245	.494	.455	+5.8
	a	2 58 00 p.....	26.0	7.25	.164	.151	.251	.490	.452	+5.2
	a	2 58 28 p.....	26.0	7.25	.163	.150	.249	.491	.453	+5.3
	a	2 58 50 p.....	26.0	7.25	.163	.150	.249	.491	.453	+5.3
	a	2 59 20 p.....	26.0	7.25	.162	.149	.248	.492	.454	+5.5
	a	2 59 54 p.....	26.0	7.25	.163	.150	.249	.491	.453	+5.3
	a	3 00 15 p.....	25.5	7.25	.163	.151	.251	.486	.452	+4.6
	a	3 00 40 p.....	25.5	7.25	.163	.151	.251	.486	.452	+4.6
	a	3 01 20 p.....	25.5	7.25	.162	.150	.250	.487	.453	+4.8
June 9	b	7 51 00 p.....	25.0	7.4	.170	.159	.263	.475	.444	+3.0
	a	8 01 00 p.....	24.5	7.4	.171	.161	.267	.470	.442	+2.3
	a	8 09 00 p.....	24.5	7.4	.166	.156	.259	.475	.447	+3.0
	a	8 15 00 p.....	24.5	7.4	.169	.159	.264	.472	.444	+2.6
	b	8 21 00 p.....	24.5	7.4	.160	.151	.250	.481	.452	+3.9
	b	8 33 00 p.....	24.0	7.4	.166	.157	.261	.470	.446	+2.3
	a	8 38 00 p.....	24.0	7.4	.169	.160	.266	.467	.443	+1.9
	b	8 42 00 p.....	24.0	7.4	.164	.155	.258	.472	.448	+2.6
	a	8 46 00 p.....	24.0	7.4	.172	.163	.270	.464	.440	+1.4
	a	8 54 00 p.....	23.5	7.4	.174	.166	.275	.458	.437	+0.5
	b	9 00 00 p.....	23.5	7.4	.169	.161	.267	.463	.442	+1.3
	a	9 10 00 p.....	23.5	7.4	.175	.167	.277	.457	.436	+0.3
	b	9 18 00 p.....	23.5	7.4	.164	.156	.259	.458	.447	+0.5
	a	9 24 00 p.....	23.0	7.4	.173	.166	.275	.458	.437	+0.5
	b	9 32 00 p.....	23.0	7.4	.172	.165	.274	.456	.438	+0.2
	a	9 38 00 p.....	22.5	7.4	.171	.165	.274	.453	.438	−0.2
	b	9 46 00 p.....	22.5	7.4	.171	.165	.274	.453	.438	−0.2

In order to obtain a better comparison between the values of R and R_a measured at different times, we may reduce them to a constant temperature, $t=20°$, $T_1=293$°C, by multiplying by the ratio $293^4/T_1^4$. The resulting values, R_{20} and R_{a20}, are in closer agreement than are R and R_a, the values obtained during the eclipse falling intermediate in value between those of June 4–5 and June 9.

But on the night of June 4–5 the diurnal fall in temperature was very great, 22°C., and there must have been a strong inversion of temperature that greatly reduced the value of R and increased R_a. Probably similar relations between R and R_a existed at the time of the eclipse, and must be attributed, not to temperature inversion, but to the influence of A.Cu. and A.St. clouds, with which the sky was from 7 to 8 tenths covered, although clear about the sun, and nearly so overhead. The mean height of this cloud layer is estimated to have been approximately 5,500 meters, and its temperature about −10°C.

In column 2 of the table the letter *a* indicates that the measurements were made with the Ångström pyrgeometer, and the letter *b* that they were made with the Smithsonian pyranometer. On June 4–5 there is no appreciable difference between the readings of the two instruments. On the 9th Ångström pyrgeometer readings averaged about 2 per cent higher than the pyranometer readings. After 8:54 p. m. the values of R_{20} obtained from pyrgeometer readings are in almost exact agreement with the average of previous measurements made by the Weather Bureau with a corresponding value of *e*.

The values of *e* in Table 1 were obtained from the readings of the thermograph and the hygrograph.

The presence of clouds during totality detracts from the value of comparisons between radiation measurements obtained at that time and on clear nights. However, there is no evidence that the exchange of radiation between the instrument and the atmosphere during totality differed in any respect from the exchange that occurs at night under like conditions of temperature, except that it was more than ordinarily steady. The electrical heating current was constantly increased until the instant of second contact, and after third contact it was constantly decreased, slowly at first, and then more rapidly. During totality there was only the slightest movement of the galvanometer needle. This was no doubt partly due to the almost total absence of surface winds, but the generally quiescent state of the atmosphere, indicating lack of abnormal temperature gradients, must have been a factor.

Throughout the path of totality the marked decrease in insolation, such as is shown by curve C in figure 1,[9] must be considered the disturbing cause that produced the meteorological changes discussed in the following sections.

METEOROLOGICAL PHENOMENA.

Studies of the meteorology of eclipses prior to that of May, 1900 (mostly those of 1878, 1883, 1887, and 1893) consist chiefly of presentations of the actual changes of the meteorological elements during the passage of the shadow, without comment in detail and without attempt at analysis. In some instances, observations were available at but one station. As will be shown later, the effect of the moon's shadow usually is too small to be measured by ordinary instruments, and for this reason, some authorities, including Symons, have doubted the reality of certain minute changes of pressure and wind that have been reported. The change of temperature is very evident and sometimes amounts to 5° C., the amount in any instance depending upon latitude, elevation above the earth's surface, whether on sea or land, and upon the time of day. A decrease of the velocity, and slight fluctuations of the direction, of the wind have been observed during some eclipses, but previous to that of 1900 no one appears to have considered these phenomena to be very important.

The eclipse of the 28th of May, 1900, occurred under circumstances very favorable for meteorological observations, and, fortunately, in and near the path of totality there were a few instruments capable of measuring small changes of pressure and wind. The change of temperature was unusually large and there were unmistakable evidences of a minute fluctuation of the atmospheric pressure and of the direction of the wind. In his analysis, Clayton prepared synoptic charts of the phenomena recorded on all sides of the area of totality, finding evidence of a feeble circulation of the wind, which, considered in its relation to the pressure and temperature, indicated the formation of a cyclone with a cold center, such as is described by Ferrel. Nearly similar results were obtained by Clayton in a study of the eclipses of 1901 and 1905; and in the instance of the eclipse of 1901 (which occurred part y north and partly south of the Equator) Van Bemmelen made the interesting discovery that the

[9] See this REVIEW for June, 1918, 46:266, for radiation measurements made at Lincoln Nebr., during the eclipse.

circulation of the eclipse-wind is different in the two hemispheres.

The importance of intensive studies of eclipse meteorology is indicated by the following quotation from Clayton's summary:

> The eclipse may be compared to an experiment by nature, in which all the causes that complicate the origin of the ordinary cyclone are eliminated except that of a direct and rapid change of temperature.

In some respects the eclipse of June 8, 1918, occurred under circumstances unusually favorable for meteorological study. The path of totality extended across the country from Oregon to Florida, an easily accessible region in which are many first-order meteorological stations, observatories, and unofficial observers; also, at the time of the eclipse temporary stations were occupied by several expeditions or observing parties from the more important observatories at a distance.

For many reasons, chiefly the abnormal conditions due to the war and the limited time that could be given to preparation, it was impossible to obtain, in time for use, the special self-recording meteorological apparatus most desirable in studies of this kind; also, it was very necessary to adopt a program that could be managed without difficulty by officials already burdened by regular work. It should be said here that all observers called upon responded promptly, and their interest and enthusiasm resulted in the collection of a larger amount of accurate meteorological information than is available for any preceding eclipse.

During the eclipse of June 8 there were obtained records of atmospheric pressure (from readings of mercurial barometers) at 41 stations; direction of the wind (from observations of a wind vane reflected in a nephoscope) and of the amount, kind, direction, relative velocity and position of clouds, at 17 stations; besides, the usual records of temperature, wind velocity, humidity, and sunshine, from automatic instruments, at all stations. On the day of the eclipse special observations were made every 10 minutes between first and last contact and every half hour for several hours before and after totality; also, to allow for local diurnal variations, observations of the direction of the wind were made every half hour from noon to 8 p. m. on every day from the 3d to the 15th of June.

The general circumstances of the eclipse and the meteorological conditions at 7 a. m., June 8, are shown in Chart XLVII-10. The path of totality is indicated by the row of red circles marking the position of the shadow at 10-minute intervals beginning with 2:50 p. m., when it appeared off the Pacific coast near Washington. To facilitate comparisons, the time of totality is expressed both in 120th meridian and local standard time when these are different; also, the time of sunset is given. These data are indicated by figures near the red circles. The limits of the belt of 90-per cent totality are indicated approximately by the two red lines north and south of and nearly equidistant from the row of red circles.

Temperature.—The most marked meteorological change was the fall of air temperature, which was recorded at all Weather Bureau stations by the thermograph. In addition, two excellent series of temperature readings, made at 10-minute intervals with a sling psychrometer, were obtained at the Weather Bureau stations at Boise, Idaho, where the sun was 99 per cent eclipsed, and at Pocatello, Idaho, which was near the center of the path of totality. A third series made at 5-minute intervals from thermometers exposed in an instrument shelter at Corona, Colo., an eclipse station of the department of terrestrial magnetism, Carnegie Institution of Washington, has been kindly communicated by the director, Dr. L. A. Bauer. Corona was also near the center of the path of totality. Its coordinates are as follows: Latitude, 39° 57′ N.; longitude, 105° 52′ W.; altitude above sea level, 11,800 feet (3,597 meters). The maximum fall of temperature recorded during this eclipse is 5° C., measured at Corona in the interval 23 minutes before totality to 7 minutes after totality. Thin cumulus clouds were present, and occasionally obscured the sun, but became thinner during the progress of the eclipse.

The above series of temperature readings are plotted on figure 2 in curves C, D, and E, respectively. In addition curve A is the diurnal temperature curve for Boise for the summer months, as given in the MONTHLY WEATHER REVIEW SUPPLEMENT NO. 6, page 17, figure 5, except that it has been raised to correspond to the temperature at Boise on the day of the eclipse. This curve has been modified slightly to give curve B, the diurnal temperature curve for Pocatello, Idaho.

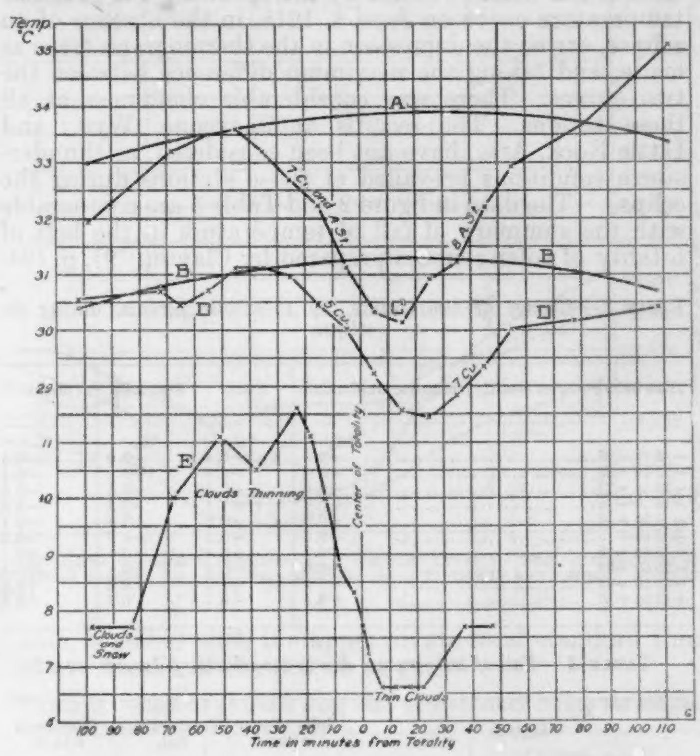

FIG. 2.—Temperature readings during the total eclipse of June 8, 1918. Curve A—Normal temperature curve for June at Boise, Idaho. Curve B—Normal temperature curve for June at Pocatello, Idaho. Curve C—Temperature readings at Boise, Idaho, during the eclipse. Curve D—Temperature readings at Pocatello, Idaho, during the eclipse. Curve E—Temperature readings at Corona, Colo., during the eclipse.

From curves C and D, respectively, it is seen that at Boise, during the half hour interval between 25 minutes before maximum solar obscuration to 5 minutes after, the fall in temperature was 2.4° C., and at Pocatello, from 15 minutes before total obscuration to 15 minutes after, the fall was 1.9° C. Expressed in rate of fall per hour these give for Boise 4.8° C., and for Pocatello 3.8° C., as compared with 4.0° C. at Goldendale, and 10.0° C. at Corona.

The above rates include not only the fall in temperature due to the eclipse shadow, but also that due to the diurnal change in temperature and to accidental causes. The effect of these two latter causes was undoubtedly small at all the above stations except Corona, for which

the diurnal temperature curve has not been determined, and where it is obvious that a marked rise in temperature occurred after the passage of a snow squall about 85 minutes before the eclipse became total.

In Table 2 is given the rate of change of temperature at Goldendale, Boise, and Pocatello for 10-minute intervals. On the average the most rapid rate of fall in temperature was observed in the interval 5 minutes before to 5 minutes after totality, and the most rapid rate of rise in the interval from 35 to 45 minutes after totality.

In Table 3 is given the fall in temperature, at several Weather Bureau stations in or near the path of totality, that is attributable to the eclipse shadow. In the case of Goldendale, Boise, and Pocatello this fall represents the maximum difference between plotted observed temperatures and the diurnal temperature curve. At other stations it has been obtained by interpolating the probable temperature curve on June 8, 1918, in the absence of an eclipse, across the depression in the thermograph trace as made, and taking the maximum difference between the two curves. There was considerable cloudiness at all these stations. The records at Cheyenne, Wyo., and Little Rock, Ark., have not been considered, as thunderstorm conditions prevailed at those stations during the eclipse. The data in figure 2 and Table 3 are comparable with the summary of fall of temperature in the belt of totality of solar eclipses prepared by Clayton (**9**), p. 194

TABLE 2.—*Change of temperature, by 10-minute periods, during the eclipse.*

Time before or after totality, minutes.	Goldendale.	Boise.	Pocatello.	Mean.
	°C.	*°C.*	*°C.*	*°C.*
−45 to −35	−0.7	−0.4	±0.0	−0.4
−35 to −25	−0.4	−0.5	−0.2	−0.4
−25 to −15	−0.6	−0.5	−0.5	−0.5
−15 to − 5	−0.4	−1.1	−0.4	−0.6
− 5 to + 5	−0.4	−0.8	−0.8	−0.7
+ 5 to +15	−0.2	−0.2	−0.6	−0.3
+15 to +25	+0.3	+0.8	−0.1	+0.3
+25 to +35	+0.6	+0.3	+0.4	+0.4
+35 to +45	+0.3	+1.0	+0.5	+0.6
+45 to +55	+0.2	+0.7	+0.7	+0.5

TABLE 3.—*Fall of temperature due to the eclipse of June 8, 1918.*

Station.	Solar obscuration.	Temperature fall.	Cloudiness 0 to 10.
	Per cent.	*°C.*	
Seattle, Wash.	98	2.2	10
Portland, Oreg.	99	2.2	9
Goldendale, Wash.	Total.	3.2	8
Baker, Oreg.	Total.	3.1	Thin cirrus.
Boise, Idaho	99	3.8	8
Pocatello, Idaho	Total.	2.8	6
Salt Lake City, Utah	97	3.9	2
Denver, Colo.	Total.	2.5	9
Dodge City, Kans.	Total.	1.7	6
Oklahoma City, Okla.	99	1.7	9

It is to be noted that falls of between 3° and 4° C. were recorded at most stations in the Plateau region, that the fall was less toward the Pacific coast, probably because of a thicker cloud cover, and that it was still less in the Plains States, partly on account of cloudiness and partly because the sun was nearer the horizon.

Atmospheric pressure changes.—Readings of the mercurial barometer made at 41 Weather Bureau stations in the path of 88 per cent or more of obscuration have been plotted pressure against time. The readings were made at 10-minute intervals during the half-hour preceding and the half hour following maximum obscuration, and at half-hour intervals during the remainder of the period noon to 8 p. m., 75th meridian time. A straight line was then drawn through the plotted pressure at the times of the beginning and the end of the eclipse and the departures of the observed pressures from this straight line, which will be designated the *apparent eclipse departures*, read off. To determine the *true eclipse departures* the mean hourly pressure values [10] for June for the stations Portland, Oreg.; Salt Lake City, Utah; Santa Fe, N. Mex.; Dodge City, Kans.; and St. Louis, Mo.; were similarly plotted, a straight line drawn through the pressure at the times of the beginning and the end of the eclipse, the departures of diurnal pressure during the time covered by the above observations from this straight line determined, and subtracted from the apparent eclipse departures for the stations nearest them.

For purposes of discussion the stations have been arranged in three groups [11]—7 stations with maximum obscuration 99 per cent or more, 12 stations south of the path of totality with maximum obscuration from 89 to 97 per cent, and 18 stations north of the path of totality with maximum obscuration from 88 to 98 per cent.

TABLE 4.—*Summary of eclipse pressure changes measured on June 8, 1918.*

Time from maximum obscuration.	Center of shadow.	South of center.	North of center.	Mean of all.		South of center.
	Maximum obscuration—per cent.					
	99-100	97-89	98-88	100-88		97-94
h. m.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*mb.*	*Inches.*
−4 30	+0.014	+0.030	−0.009	....	....	+0.029
−4 00	+ .010	+ .023	− .003	+0.0091	+0.31	+ .026
−3 30	+ .008	+ .017	± .000	+ .0067	+ .23	+ .018
−3 00	+ .008	+ .011	− .001	+ .0048	+ .16	+ .010
−2 30	+ .004	+ .011	− .001	+ .0038	+ .13	+ .006
−2 00	− .001	+ .003	− .001	+ .0001	± .00	± .000
−1 30	± .000	± .000	− .001	− .0004	− .01	− .002
−1 05	− .001	− .002	± .000	− .0011	− .04	− .002
−0 55	− .002	− .003	± .000	− .0014	− .05	+ .001
−0 45	− .003	− .003	− .001	− .0019	− .06	+ .003
−0 35	− .003	− .002	− .002	− .0019	− .06	+ .001
−0 25	− .007	− .003	− .003	− .0038	− .13	± .000
−0 15	− .008	− .004	− .004	− .0049	− .17	+ .001
−0 05	− .008	− .006	− .004	− .0056	− .19	− .004
+0 05	− .008	− .006	− .003	− .0052	− .18	− .003
+0 15	− .008	− .006	− .003	− .0051	− .17	− .005
+0 25	− .008	− .005	− .003	− .0044	− .15	− .006
+0 35	− .004	− .004	− .003	− .0034	− .12	− .006
+0 45	− .004	− .003	− .001	− .0022	− .07	− .004
+0 55	± .000	− .002	− .001	− .0008	− .02	− .001
+1 05	± .000	± .000	± .000	+ .0001	± .00	± .000
+1 15	....	± .000	+ .001	+ .0007	+ .02	+ .001
+1 25	....	+ .001	+ .001	+ .0014	+ .05	+ .002
+1 35	+ .004	+ .002	+ .004	+ .0022	+ .07	+ .003

NOTE.—In the first column the − (minus sign) = time before totality; + (plus sign) = time after totality.

In Table 4 are given the means of the true eclipse departures for the three groups of stations, and also for all the stations, the latter expressed in both inches and millibars. The departures in inches are also shown graphically in figure 3, where the curve for all the stations combined, curve *M*, has its scale of abscissas lowered by 0.004 inch as compared with the abscissas for the other three curves.

The 8 a. m. and 8 p. m. weather maps of June 8 show that no decided pressure changes were taking place along

[10] See "Monthly mean values for the lustrum, 1891-95," by A. J. Henry, in Report of the Chief of the Weather Bureau, 1896-97, pp. 78-91.

[11] The stations in each group are as follows: *Near center of totality*—Portland, Oreg.; Baker, Oreg.; Boise, Idaho; Pocatello, Idaho; Denver, Colo.; Dodge City, Kans.; Oklahoma, Okla.; *south of totality*—Roseburg, Oreg.; Reno, Nev.; Salt Lake City, Utah; Grand Junction, Colo.; Santa Fe, N. Mex.; Roswell, N. Mex.; Abilene, Tex.; Fort Worth, Tex.; Dallas, Tex.; College Station, Tex.; Palestine, Tex.; Shreveport, La.; *north of totality*—Seattle, Wash.; Spokane, Wash.; Walla Walla, Wash.; Kalispell, Mont.; Helena, Mont.; Yellowstone Park, Wyo.; North Platte, Nebr.; Lincoln, Nebr.; Drexel, Nebr.; Concordia, Kans.; Topeka, Kans.; Wichita, Kans.; St. Joseph, Mo.; Kansas City, Mo.; Springfield, Mo.; Columbia, Mo.; St. Louis, Mo.; and Cairo, Ill. Observations at Sheridan, Wyo.; Cheyenne, Wyo.; Pueblo, Colo.; and Little Rock, Ark.; had to be disregarded on account of irregularities in the pressure caused by thunderstorm conditions at these stations near the time of maximum obscuration.

the central path of the eclipse. From a study of the plotted pressures for the individual stations it appears that during the three hours preceeding the eclipse in general there was a slight decrease in pressure. Near the central line of the eclipse there was a slight increase in pressure 10 or 15 minutes before first contact, a slight decrease from first contact until 35 minutes before maximum obscuration, a more rapid decrease, lasting about 20 minutes, to a maximum depression of 0.008 inch, which was maintained from 15 minutes before until 25 minutes after maximum obscuration, and was followed by a gradual increase in pressure. South of the path of totality the curve was of much the same character, except that the first increase in pressure occurred just after, instead of just before, first contact, and the maximum depression was only 0.006 inch. North of the path of totality the first increase in pressure occurred at about the time of first contact, the maximum depression was only 0.004 inch, and was not maintained after totality.

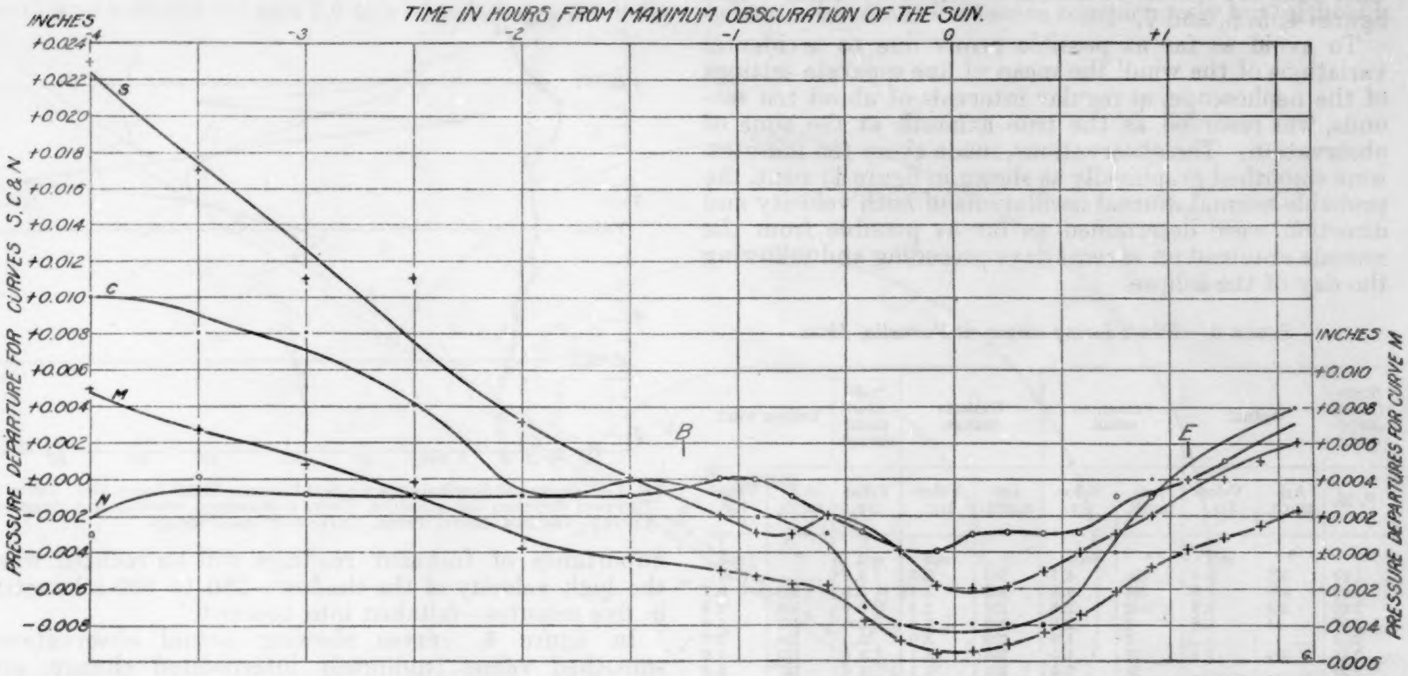

FIG. 3.—Atmospheric pressure departures from normal due to the solar eclipse of June 8, 1918. Curve M—Mean of departures at 37 stations. Curve C—Mean of departures at 7 stations in or near path of totality. Curve N—Mean of departures at 18 stations north of path of totality. Curve S—Mean of departures at 12 stations south of path of totality. B—Approximate time of beginning of eclipse. E—Approximate time of ending of eclipse.

The curve of mean departures for all the stations resembles that obtained by Fergusson at Washington, Ga., on May 28, 1900 (**6**), except that his maximum depression was only 0.004 inch and occurred between 25 and 40 minutes after totality. In the curves for the different groups of stations there is evidence of a ring of high pressure about the eclipse area; but the only indication of increased pressure near the center of the eclipse, which Clayton (**8**) has pointed out we should expect, is a decided flattening of the curve at about the time of maximum obscuration. Indeed, while individual stations show increased pressure at about this time, the only group of stations based upon any logical station classification, showing such a rise, is a group of six stations on the south side of the path of totality having a maximum obscuration of from 94 to 97 per cent. The mean eclipse departures for this group are shown in the last column of Table 4.

Probably most of the differences between eclipse departures at individual stations and the mean departures for a group of stations are due to unstable atmospheric conditions, which in several localities approached thunderstorm conditions.

A recording mercurial barometer of the siphon type at Washington, D. C., having on its record sheet a time scale of about 0.22 inch per hour and a pressure scale of 0.20 inch of mercury per inch of space, gave no indications of eclipse pressure changes. However, the maximum obscuration was only 74 per cent, and occurred about one hour and 10 minutes before sunset.

Winds.—In Table 5 are given the stations at which data of direction (azimuth) and velocity of the wind are available, together with the approximate local standard time of occurrence of the eclipse at each.

TABLE 5.—*Stations at which wind data were obtained during the eclipse.*

Station.	Time of— Beginning of eclipse.	Middle of eclipse.	Ending of eclipse.
	p. m.	*p. m.*	*p. m.*
Seattle, Wash	1:37	2:56	4:08
Portland, Oreg	1:38	2:58	4:11
Pocatello, Idaho	1:58	3:12	4:21
Winnemucca, Nev	1:52	3:12	4:22
Cheyenne, Wyo	3:10	4:21	5:25
Denver, Colo	3:12	4:24	5:27
Modena, Utah	3:03	4:25	5:26
El Paso, Tex	3:23	4:36	5:37
Lincoln, Nebr	4:18	5:25	6:26
Drexel, Nebr	4:19	5:25	6:25
Topeka, Kans	4:23	5:28	6:28
Wichita, Kans	4:23	5:29	6:31
Fort Smith, Ark	4:29	5:34	6:36
Little Rock, Ark	4:30	5:35	6:23
Oklahoma, Okla	4:26	5:32	6:27
St. Louis, Mo	4:27	5:30	6:27
Evansville, Ind	4:26	5:32	6:26

The duration of totality decreased from 2 minutes 2 seconds at Seattle to 1 minute 11 seconds at the Arkansas-Oklahoma boundary near Fort Smith.

The width of the path of totality decreased from 110 kilometers at Seattle to 85 kilometers at the Mississippi River.

The velocity of the shadow increased from about 56 kilometers per minute at Seattle to 110 kilometers per minute at the Mississippi River.

The wind velocities were obtained from the records of anemographs and are for the five-minute period ending with the time under which they are entered. The directions or azimuths from which the wind blew are expressed in degrees, beginning with South (0°) and reading clockwise through West (90°), North (180°), and East (270°) to South.

The Clayton method of analysis has been followed, and this, with the results obtained, is shown by Table 6 and figures 4, 5, 6, and 7.

To avoid as far as possible errors due to accidental variations of the wind, the mean of five separate settings of the nephoscope, at regular intervals of about ten seconds, was recorded as the true azimuth at the time of observation. The observations, made every ten minutes, were smoothed graphically as shown in figure 4; next, the probable normal diurnal oscillations of both velocity and direction were determined as far as possible from the records obtained on several days preceding and following the day of the eclipse.

TABLE 6.—*Winds during eclipse, at Pocatello, Idaho.*

Time. (Local standard.)	Actual.		Smoothed mean.		Uniform change.		Probable mean change.	Eclipse wind.	
P. M.	Azimuth.	Velocity.	Azimuth.	Velocity.	Azimuth.	Velocity.	Velocity.	Azimuth.	Velocity.
	°	m/s	°	m/s	°	m/s	m/s	°	m/s
1:30	322	5.4	336	4.7	344	2.5	3.1	......	......
1:45	339	4.0	341	4.0	347	2.7	3.3	315	0.7
2:00	359	2.6	352	2.6	350	2.9	3.4	165	0.8
2:07	44	1.8	1	2.0	352	3.0	3.5	160	1.6
2:12	......	......	7	1.9	353	3.0	3.5	156	1.7
2:17	334	1.8	15	1.9	353	3.1	3.6	153	1.9
2:22	......	......	23	2.0	354	3.1	3.6	147	2.0
2:27	18	2.2	29	2.2	355	3.2	3.7	142	2.2
2:32	......	......	37	2.6	356	3.3	3.7	131	2.4
2:37	50	4.0	42	3.0	357	3.4	3.8	126	2.6
2:42	......	......	46	3.4	357	3.4	3.8	119	2.8
2:47	91	3.1	47	3.4	0	3.5	3.9	121	3.0
2:52	......	......	47	3.4	0	3.6	3.9	122	2.8
2:57	50	3.6	46	3.4	1	3.7	3.9	122	2.8
3:02	......	......	41	3.3	2	3.7	3.9	125	2.3
3:07	25	3.0	31	3.2	4	3.8	3.9	129	1.8
3:12	......	......	21	3.1	5	3.8	3.9	142	1.2
3:17	10	3.1	18	3.1	6	3.9	3.9	149	1.1
3:22	......	......	17	3.2	7	3.9	3.9	149	0.9
3:27	18	3.6	19	3.2	8	4.0	3.9	150	0.8
3:22	......	......	23	3.3	9	4.1	3.9	140	1.0
3:37	29	3.1	24	3.5	10	4.2	3.9	131	1.0
3:42	......	......	25	3.9	11	4.3	3.9	107	0.9
3:47	25	4.5	23	4.2	12	4.4	3.9	88	0.8
3:52	......	......	22	4.3	12	4.4	3.9	79	0.8
3:57	17	4.5	21	4.4	13	4.5	3.9	68	0.7
4:02	......	......	20	4.4	14	4.5	3.9	58	0.7
4:07	23	4.0	20	4.4	16	4.6	3.9	47	0.6
4:12	......	......	19	4.6	18	4.7	3.8	24	0.7
4:30	15	5.4	17	5.0	20	4.8	3.8	9	1.2
4:45	......	......	16	5.3	23	5.1	3.6	......	......
5:00	15	5.4	15	5.4	26	5.4	3.4	......	......

To obtain the eclipse wind, it was assumed, as in the instance of the pressure and temperature, that any departure of the observed wind from the normal would probably be due to the eclipse; and in the absence of a satisfactory normal, that the departure from a straight line connecting the directions at the beginning and ending of the eclipse were due to the eclipse. In a few instances, for comparison, the eclipse winds were obtained from both normal and straight-line change, but no important differences were found.

Referring to Table 6, which shows in detail the observations at Pocatello, the actual observations appear in the second and third columns, smoothed values in the next two; the sixth and seventh columns contain the values of an assumed uniform change during the time occupied by the eclipse, and the eighth column the normal or probable mean change. The last two columns contain the resultant eclipse winds. In order to secure greater smoothness and detail, the smoothed values and normals were read at five-minute intervals. The

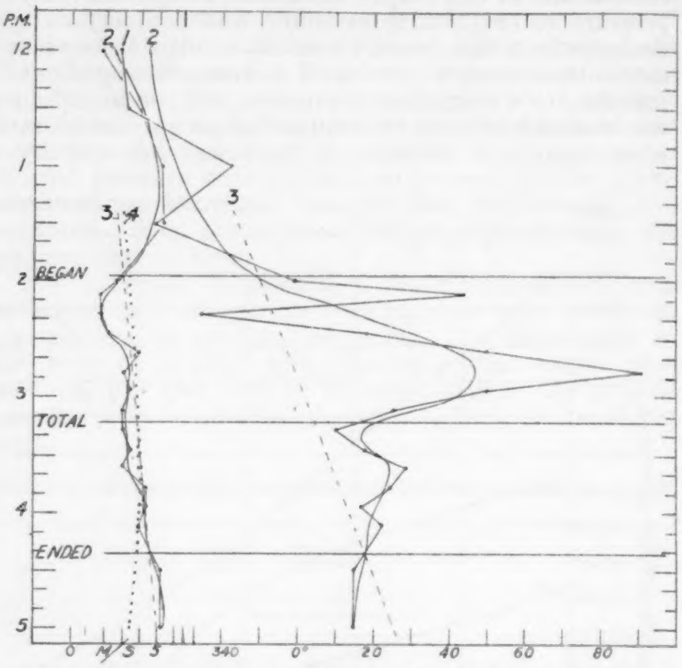

FIG. 4.—Velocity and direction of the winds at Pocatello, Idaho, June 8, 1918. Curve 1—Observed directions and velocities. Curve 2—Smoothed velocities and directions. Curve 3—Assumed uniform change. Curve 4—Probable change.

importance of frequent readings will be realized when the high velocity of the shadow—280 to 600 kilometers in five minutes—is taken into account.

In figure 4, curves showing actual observations, smoothed values, uniformly interpolated change, and

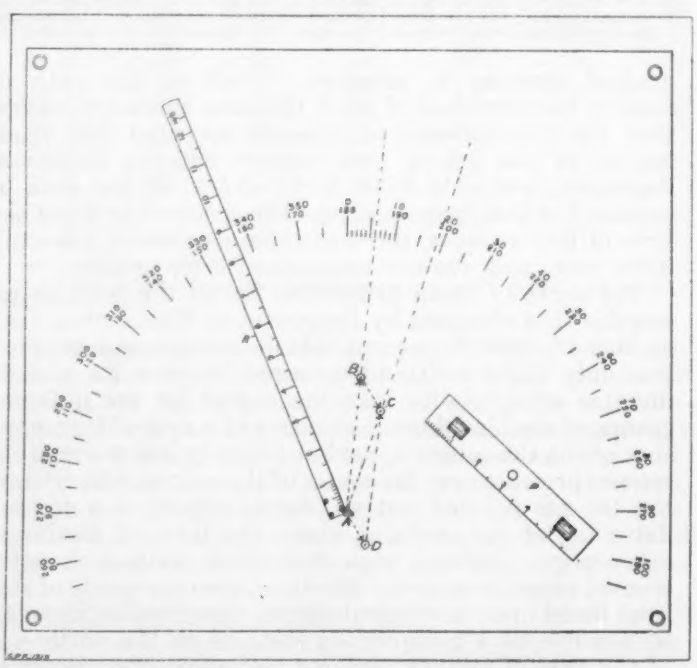

FIG. 5.—Method of obtaining resultant or eclipse winds.

normal change are indicated, respectively, by the numbers 1, 2 3, and 4.

The values of the eclipse wind were obtained by means of the special plotting device shown in figure 5, which had been used by Mr. Fergusson in reducing observations of *ballons-sondes* in 1906, and which, because of its

obvious usefulness in other studies, appears worth describing in detail. To an ordinary drawing board or table is secured a paper protractor or arc of large radius (preferably at least 25 cm.) graduated to whole degrees. In the center of this arc (*A*) is pivoted an arm (*R*) upon which is ruled a scale, whose zero is the axis of the arm. Azimuths are indicated by the point of intersection of the edge of the arm with the arc, and velocities by the scale on the arm. For example, at Pocatello at 3:17 p. m., the smoothed azimuth and velocity of the wind (18° and 3.1 m/s respectively) are indicated by the dotted line *A* and small circle *C*. The normal or assumed azimuth and velocity (6° and 3.9 m/s respectively) are indicated by the dotted line and circle *A–B*. Completing the parallelogram of forces, *A–D* indicates the resultant or eclipse wind. In practice, it is only necessary to mark the points (represented by circles) *B* and *C*, employing a rolling parallel ruler *P* (upon which also is ruled a velocity-scale) to measure both resultant azimuth and velocity *A–D* in one operation. With the rather wide velocity scale of 30 mm. for each meter per second adopted for this work, readings were made direct to tenths of a meter per second. The errors of plotting, etc., except, perhaps, in a few instances of very small changes, rarely exceeded one or two degrees.

In figures 6 and 7, respectively, are shown the smoothed observations at 10-minute intervals, and the resultant eclipse winds at 5-minute intervals, plotted with reference to the position of the shadow. The increasing width of the spaces between the arrows representing directions of the winds at regular intervals of time after totality is due to the increasing velocity of the shadow towards sunset, and should not be understood to mean fewer observations in the rear of the shadow.

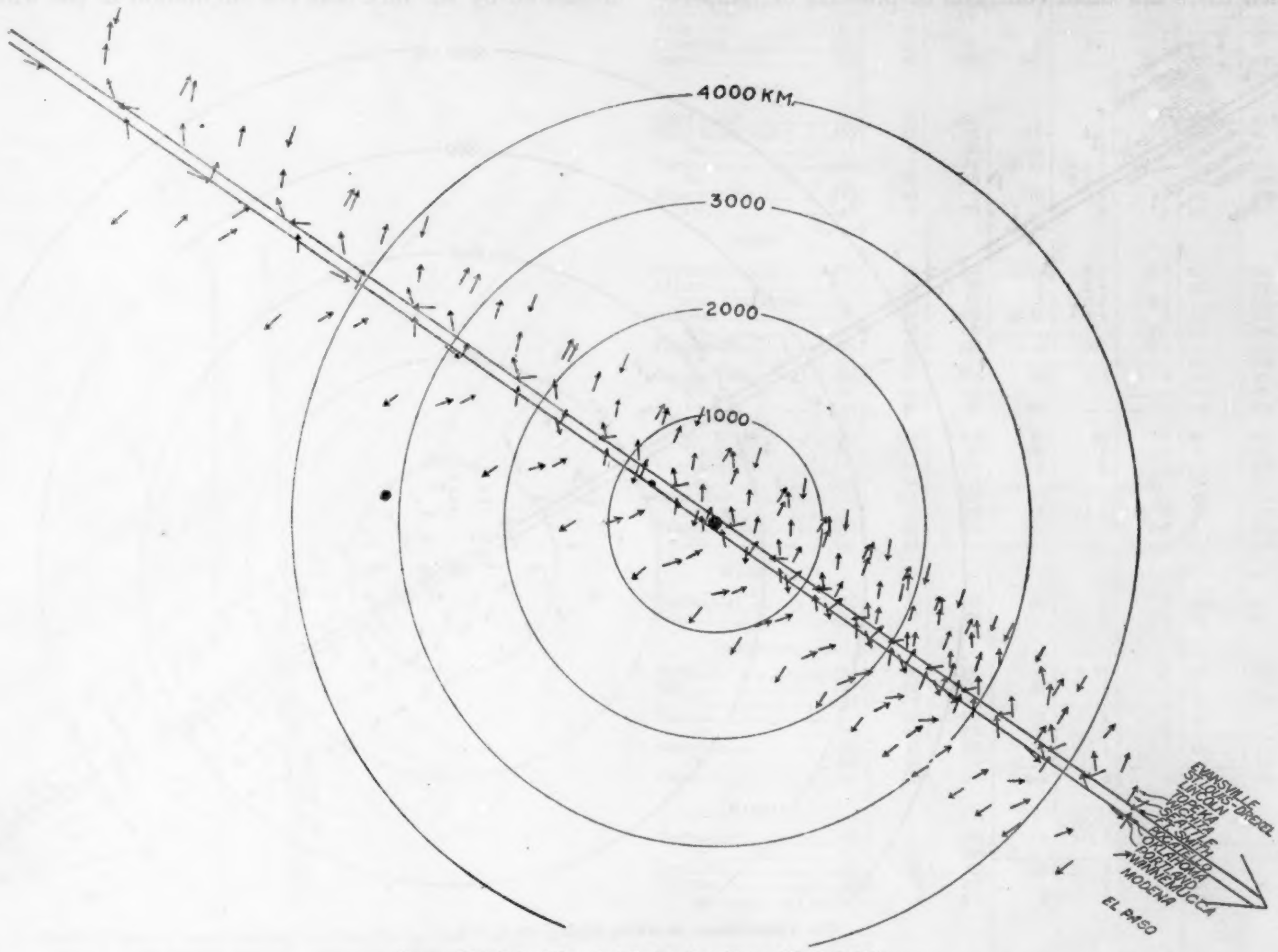

FIG. 6.—Direction of the wind during the eclipse of June 8, 1918.

The results of the analysis described, as indicated by figures 6 and 7, are as follows:

1. The influence of the eclipse upon the natural wind was noticeable at practically all stations, and in figure 6 is indicated by the tendency of the arrows representing azimuths to incline toward the shadow. This effect is quite distinct at Portland, El Paso, and other stations.

The resultant or eclipse winds plotted in figure 7, indicate the same effect more conspicuously but, although successive observations at the same station are fairly consistent, there are important differences between stations near together, such as Lincoln and Drexel, that can not be attributed to a different effect of the eclipse.

2. Other than the general tendency of the wind to blow toward the shadow, the observations do not indicate a definite circulation about the area of minimum temperature.

Consideration of all the known circumstances of the eclipse in connection with the meteorological results indicates that very probably the discordances referred to, as well as the absence of a circulation of the winds, may be due, partly at least, to the following modifying influences:

(1) As shown in table 5, at 8 of the 14 stations the maximum obscuration did not occur until nearly 5:30 p. m., and the eclipse ended about an hour later. Also,

the velocity of the shadow so near sunset was twice as great as it was on the Pacific coast about 3 p. m., the shadow was smaller, and the duration of totality shorter; consequently, the maximum depression of temperature due to the eclipse, following some minutes after totality, occurred at a time when the sun's energy was comparatively feeble and the effect upon the atmosphere small.

(2) The meteorological conditions on the afternoon of June 8 were generally unfavorable. The accompanying synoptic chart of the distribution of pressure and temperature at 7 a. m. on June 8 (Chart X), indicates the condition known as a "flat" map, i. e., one in which there are small contrasts of pressure or tempera-

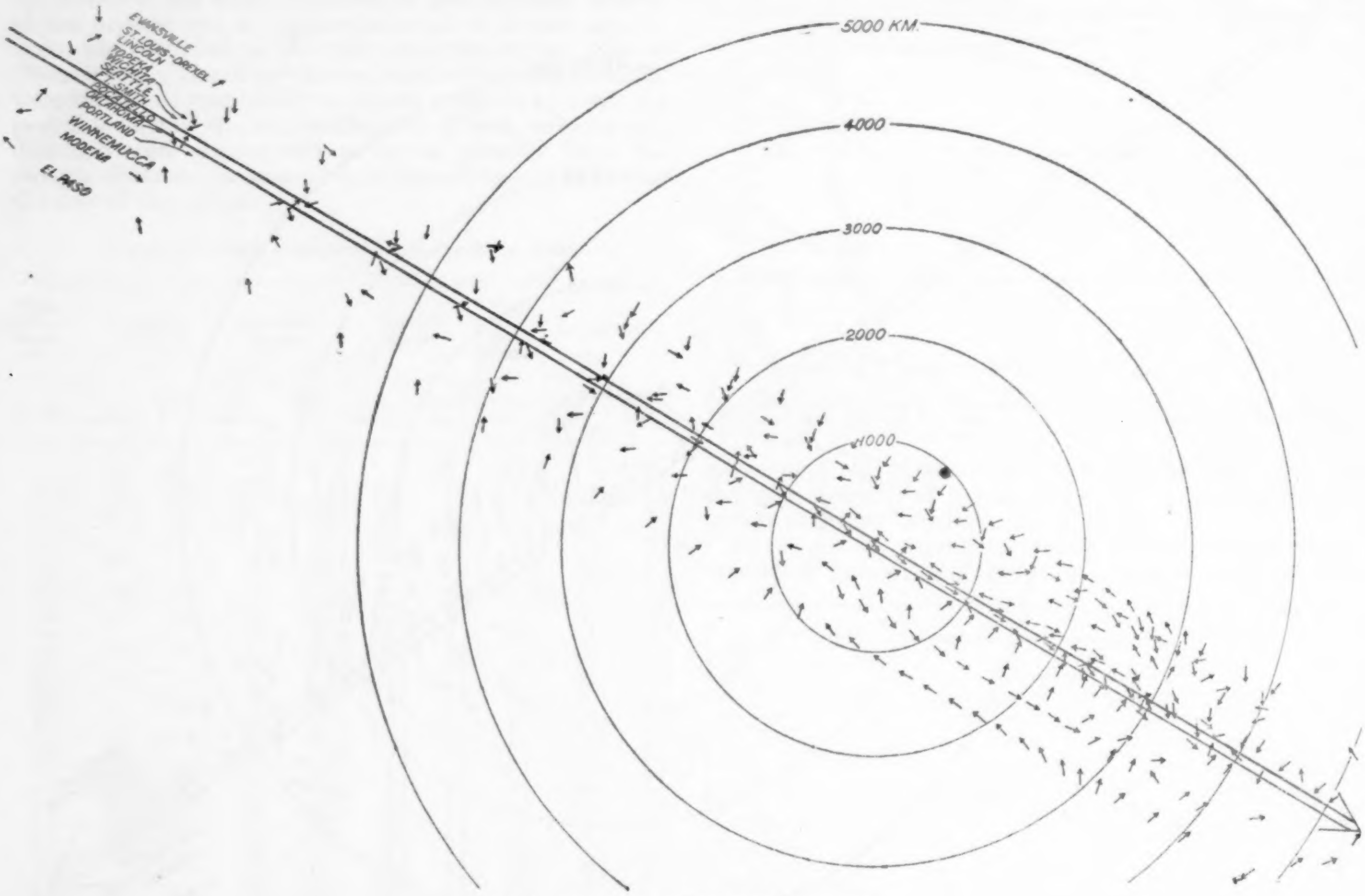

FIG. 7.—Resultant, or eclipse winds, June 8, 1918.

ture and light and variable winds. Such a condition is very favorable for the development of local storms (which actually occurred over a large part of the territory crossed by the shadow at the time the eclipse was in progress) and for a greater and more irregular variability of both direction and velocity of the wind than usual. This was particularly true of the records at Denver, Cheyenne, and Little Rock, where showers occurred during the passage of the shadow, and the variability of the wind was so unusual that the records could not be used.

(3) Influence of topography, etc., upon the direction and velocity of the wind recorded at some stations. The stations most favorably situated as regards the time of the eclipse, unfortunately, were near high mountains and in all probability the records at a few stations were affected more or less by local surroundings. A study of these records with reference to topography and other local conditions is in progress, and if the results justify it will be made the subject of another paper.

The velocity of the eclipse wind, due to the comparatively small temperature gradient caused by the shadow, can never be large, and in the present instance exceeded 2 meters per second at but three stations near the path of totality. It may be so modified by local surroundings, or so masked by local conditions, or both, that it can not be detected at one station, although conspicuous at another not far away. Consequently, it is not to be expected that all the more interesting or important phenomena will be recorded during all eclipses. This is illustrated by the fact that the circulation of the winds found during the eclipses of 1900 and 1901 was not observed during the eclipses of 1905 and 1918.

In order that the utmost may be obtained from future studies of the meteorology of solar eclipses, all stations of observation should be carefully selected by the authority in charge of the work, and equipped with adequate self-recording apparatus. The use of special barographs and anemographs in the present investigation would have saved at least two-thirds of the time of the observers and one-half the time found necessary in analyzing the observations.

Cloud data.—(To be discussed in a later REVIEW.)

SHADOW-BAND OBSERVATIONS.

Clouds prevented the appearance of shadow-bands at many places, but at a few points, principally at cooperative stations of the Weather Bureau, data were

obtained in accordance with instructions sent out from the central office. These data have been summarized in Table 7, from which it appears that generally the bands lay across the path of totality, and advanced in the same general direction as did the area of totality. There were exceptions to this rule, however, as, for example, at Springfield, Idaho, where the direction of the bands before totality (azimuth, 315°)[12] was nearly *parallel* to the path of totality and to the direction of motion of the bands; also after totality, with the direction of the bands nearly at *right angles* to the path of totality, their direction of motion was also nearly at right angles to this path. The

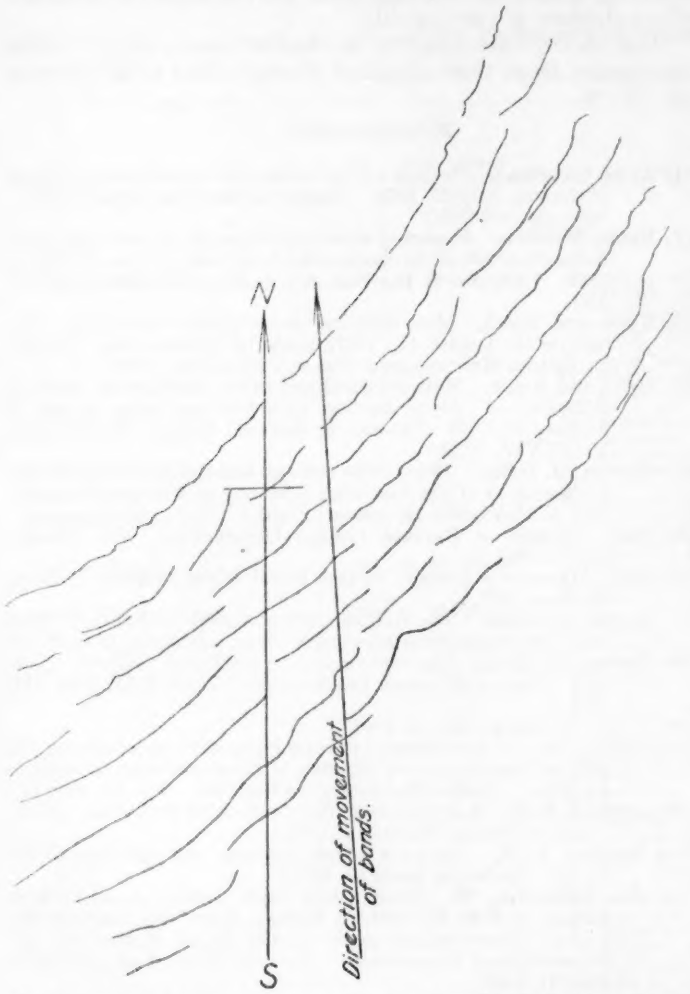

FIG. 8.—Sketch of shadow bands observed at Grace Power Plant, Idaho, on June 8, 1918, G. I. McFarland, observer. Eclipse approaching totality.

six different observers at Goldendale, Wash., were in close agreement as to both the direction of the bands and their direction of motion.

An explanation of the lack of agreement in the direction of the bands may be found in the fact that according to several observers the bands were not straight, but crescent-shaped, as shown in figure 8.

The estimates of velocity appear to be of little value except that they indicate a movement comparable to that of the wind at a considerable altitude.

There is also great disparity in the estimates of the width and separation of the bands. The most common estimate was from 2 to 4 inches wide, and from 3 to 4 inches apart.

[12] Azimuths are expressed the same as for wind directions. See p. 12.

TABLE 7.—*Shadow-band observations, solar eclipse, June 8, 1918.*

State and station.	Azimuth of bands.	Azimuth of motion from.	Velocity (feet per second).	Width.	Distance apart.	Direction of wind.	Direction of clouds.
WASHINGTON.	°	°		*Inches.*	*Inches.*		
Goldendale..............(b)	25	115	30	......	......	wnw.	w.
(Mr.and Mrs.Graham)(a)	25	115	30	......	......	w.	w.
Goldendale..............(b)	39	135	......	......	......	......	......
(Dr. Brashear.)							
Goldendale..................	40	135	......	......	10	......	......
(Dr. Swasey.)							
Goldendale..............(b)	55	135	10	10	......	......	......
(Dr. Plaskett).........(a)	45	135	......	......	......	......	......
Goldendale..............(b)	39	135	3-4	2	8	......	......
(Dr. Young)...........(a)	48	......	......	......	......	......	......
Goldendale..............(b)	45	135	3	......	......	......	......
(Dr. Fath).............(a)	48	......	......	......	......	......	......
Glenwood...............(b)	20	80	3	2+	2	sw.	w.
Laurel...................(b)	45	135	6-7	......	2-3	nw.	nw.
OREGON.							
Hood River.............(b)	45	135	1	1	2	......	se.
Hood River Valley.....(b)	45	45	200	2	3	nw.	w.
Do....................a)	0	90	200	2	3	nw.	w.
Union...................(b)	0	94	40-45	0.5-2	6-14	nw.	nw.
Do....................(a)	70	110	......	0.5-2	......	nw.	nw.
Reservoir No. 3.........(b)	45	0	10	3	3	ne.	w.
Do....................(a)	0	90	15	2	3	ne.	w.
IDAHO.							
Placerville..............(b)	38	128	......	2.5	2.5	s.	sw.
Atlanta..................(b)	45	90	3	2.5	4	ne.	sw.
(Boise King mine)....(a)	45	90	3	0.5	3-4	......	sw.
Atlanta..................(b)	10	300	10-15	3-4	5	se.	sw.
Do....................(a)	40	290	......	......	5+	se.	sw.
Pioneerville............(b)	40	135	4	2-4	2-4	sw.	sw.
Do....................(a)	40	......	......	......	......	sw.	sw.
Garden Valley..........(b)	85	355	15	2-5	6	nw.	w.
Do....................(a)	85	355	......	......	......	nw.	w.
Do....................(b)	45	90	88	......	......	sw.	nw.
(Pyle Creek.)							
Crystal Rock............(b)	215	135	10	10	36	w.	w.
Do....................(a)	(?)	90	250	4	36	w.	w.
Aberdeen................(b)	64	124	9	3	3	sw.	nw.
Do....................(a)	64	124	......	......	......	sw.	nw.
Springfield.............(b)	315	320	20	6-8	24	sw.	nw.
Do....................(a)	45	220	10	4-8	24-36	n.	nw.
Grace...................(b)	45	359	37	1	4-6	s.	nw.
Do....................(a)	45	......	......	......	......	s.	nw.
WYOMING.							
Centennial..............(b)	90	158	37	7	7	nw.	n.
Eden....................(b)	315	90	......	2	4	w.	se.
COLORADO.							
Eads.....................(a)	90	180	2	0.75	10	se	nw.
Lay......................(b)	88	171	20	4	4	n.	sw.
Do....................(a)	6	93	......	......	......	w.	sw.
Yampa...................(b)	45	315	20	2	4	n.	......
Do....................(a)	0	270	30	2	3	......	......
Grand Lake.............(b)	45	135	20	1	1	se.	w.
Do....................(a)	90	135	......	......	......	......	w.
Corona[1]...............(a)	75	150	2.5-3	4	8	nw.	sw.
KANSAS.							
Coldwater...............(b)	40	315	6	1-1.7	1-1.7	......	......
Do....................(a)	45	135	......	......	......	......	......
Santa Fe................(a)	45	135	30	3	5-6	sw.	......
Tribune.................(b)	0	315	......	2	3	se.	w.
Do....................(a)	0	270	8	2	2	nw.	w.
OKLAHOMA.							
McAlester...............(b)	90-135	135	29	3	5-6	......	nw.
Do....................(a)	135	135	......	......	......	......	nw

[1] Eclipse station, department of terrestrial magnetism, Carnegie Institution of Washington. Data furnished by the director, Dr. L. A. Bauer.

NOTE.—(b) signifies before totality; (a) after totality.

Description of shadow bands.—The following are extracted from the reports of the different observers:

Goldendale, Wash.—Mr. Graham: Continuous bands following each other closely; distinct before totality, faint after totality.

Dr. Brashear: Bands plainly seen and were brightest on the preceding side.[13]

Dr. Swasey: Most plainly visible about a half minute before totality came and about 10 seconds after totality passed.[13]

Dr. Plaskett: Shadow bands more prominent after than before totality.[13]

[13] Extracted from Publications of the Astronomical Society of the Pacific, August, 1918, 30: 238-239.

Dr. Reynold Young: Shadow bands near beginning of totality visible 15 to 20 seconds before to 2 or 3 seconds after. Bands dark, with no color. The crest seemed broken more than could be accounted for by irregularities in white cloths spread on the ground. Bands seemed about 1 inch wide when first visible and fairly faint. As they grew plainer they seemed under 2 inches. Bands not so plainly observed after totality was passed.[13]

Dr. E. A. Fath: Shadow bands appeared at least one-half minute before totality and continued to totality; then again immediately after close of totality and continued at least one-half minute. Bands were approximately parallel and consisted of alternate bands of light and shade. They were not sharply defined and appeared a variable width so far as shadow part was concerned. Bands seen nearest beginning and ending of totality were best defined.[13]

Glenwood, Wash.—Mrs. Mary McCumber: The bands were just broken, wavering irregular lines, black-like shadows, with white spaces between. They were fainter before totality than afterward. At about the center of the lines there seemed to be a distinct white space or line about 2 inches wide. This was seen after totality. Before totality the lines were more blurred and were indistinct, like black shadows with light spaces between. These spaces were irregular like a dark line, but much narrower.

Hood River, Oreg.—(Miss) Pauline Geballe: The bands seemed to be curved, not straight, and resembled the shadows of smoke, or hot air waves. Bands were continuous.

Union, Oreg.—W. B. Davis: Lines well defined and perfect before totality; broken up after totality. Their appearance on the cloth was suggestive of heat waves rising over a stove.

Pioneerville, Idaho.—J. M. Clarke: The bands seemed to flicker like heat rising from the ground.

Garden Valley, Idaho.—P. V. Smith: The bands were merely dark waves.

J. W. Kimball: The bands were wavy and decidedly crescent shaped, concave toward the east.

Grace, Idaho.—G. I. McFarland: The bands were not distinct enough to photograph with an ordinary camera. They were about 1 inch wide, about 4 to 6 inches apart, and very wavy and somewhat disconnected. They did not move in a direction at right angles to their axes. They were rather indistinct both before and after the eclipse, although somewhat plainer after. This may be due to the fact that the pupil of the eye had opened somewhat during the eclipse and for that reason bands were more easily seen. They appeared to the observer like heat waves If you ever sat in a room in winter time with a stove so situated that the sun shone across it and cast a shadow on the wall, you have noticed the shadow of the heat waves projected. These waves are wrinkly and seem to flutter as they move. This is the way these bands appeared to us. The bands were not straight, but curved. (See fig. 8.)

Centennial, Wyo.—Louis A. Gregory: Waves of a zigzag nature, which resemble very much the heat waves that can be seen rising from the ground on almost any warm day. These waves lasted a trifle more than a half minute. They seemed a continual stream during the time they appeared, with no spaces between them.

Eads, Colo.—John P. Sanborn: To me the bands seemed to be slightly curved, with the east end traveling faster than the west end, giving a spiral effect.

Yampa, Colo.—Mrs. Mattie C. Williams: Bands very indistinct before totality, but plainly visible after totality. The first bands were made up of dark patches and flickered; the last ones were very straight and wavy.

Coldwater, Kans.—Lawton Stanley: The bands were wavy, more or less broken, and the width and distance apart seemed to vary. The bands had much the appearance of heat waves in the air on a hot summer day. They were wavy, irregular bands of gray, light and dark, almost black, shadows. The presence of these bands was noticed but a few seconds before and a few seconds after totality, probably not to exceed 10 seconds.

Tribune, Kans.—M. W. Kirkpatrick: The bands flashed across the sheet in much the same manner as the light flashes on a movie screen before pictures are shown. They flickered, were decidedly wavy in appearance, and at times seemed to begin and end on the sheet.

From the above descriptions, it appears that the bands were most plainly seen immediately before the beginning or just after the ending of totality. Even such skilled observers as Dr. Plaskett and Dr. Young, observing at the same place, do not agree as to whether the bands were the more distinct just before or just after totality. The reason for this may have been the condition of the eyes of the observers, as suggested by Mr. McFarland, Grace, Idaho.

It is significant that so many observers call attention to the resemblance of the shadow bands to bands formed by convection in the atmosphere over a heated surface. This tends to confirm the assumption that the bands are an atmospheric phenomenon, perhaps produced by ripples set up in the narrow annular space about the area of totality, where the change from partial sunshine to complete shadow is very rapid.

The above data relative to shadow bands do not differ materially from that obtained during other solar eclipses (4) (12) (16).

[13] Extracted from Publications of the Astronomical Society of the Pacific, August, 1918, 30: 238-239.

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PROPOSED MAGNETIC AND ALLIED OBSERVATIONS DURING THE TOTAL SOLAR ECLIPSE OF MAY 29, 1919.

By Dr. L. A. BAUER, Director.

[Dated: Washington, February 15, 1919.]

Special magnetic and allied observations will be made at certain stations inside and outside the shadow belt of the total solar eclipse of May 29, 1919, by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and by various magnetic observatories, institutions, and individuals who have offered their cooperation. The stations of the department of terrestrial magnetism will be probably: (1) La Paz, Bolivia; (2) Huancayo (north of belt of totality); (3) near Sobral, Brazil; (4) Ile Principe or Libreville, French Congo; (5) stations outside of belt totality by field parties as found possible. At station 3 complete magnetic and electric observations will be attempted.

It is hoped that full reports will be forwarded as soon as possible for publication in the journal of *Terrestrial Magnetism and Atmospheric Electricity*. Those interested are referred to the results of the observations made during the solar eclipse of June 8, 1918, the publication of which was begun in the September, 1918, issue of the journal. A summary of the magnetic results obtained is given in the March, 1919, issue.

HALO PHENOMENA OBSERVED DURING JANUARY, 1919.

By WILLIS RAY GREGG, METEOROLOGIST.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of— Beginning.	Time of— Ending.	Theodolite readings. Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m.	° '	° '						°	°	°	°	°
Broken Arrow, Okla.*	233	36 02	95 49	3	Solar halo, 22°	8:15 a. m.	8:30 a. m.						
					Parhelian, 22°, right	7:34 a. m.	8:30 a. m.						
					Parhelian, 22°, left	7:34 a. m.	8:30 a. m.						
				4	Solar halo, 22°	11:22 a. m.	12:00 m.						
				10	Solar halo, 22°	10:55 a. m.	1:00 p. m.						
				11	Lunar halo, 22°	6:40 p. m.	6:45 p. m.						
				13	Solar halo, 22°	9:15 a. m.	1:30 p. m.	9:20 a. m.	22	23	270		17.5
				15	Solar halo, 22°	1:00 p. m.	2:20 p. m.	2:20 p. m.	22	23	180		27
				15	Lunar halo, 22°	7:30 p. m.	8:30 p. m.						
				24	Solar halo, 22°	3:15 p. m.	4:00 p. m.	3:35 p. m.	22	23	190		19.5
				25	Lunar halo, 22°	D. N., a. m.	6:25 a. m.				360		
				25	Solar halo, 22°	10:50 a. m.	2:30 p. m.	10:55 a. m.	22	23.5	360		30
Canton, N. Y.	137	44 36	75 10	6	Solar halo, 22°	2:00 p. m.	3:00 p. m.						
				22	Solar halo, 22°	11:00 a. m.	11:35 a. m.						
				28	Solar halo, 22°	11:20 a. m.	12:35 p. m.						
Cincinnati, Ohio	191	39 06	84 30	7	Solar halo, 22°	11:05 a. m.	11:20 a. m.						
				13	Lunar halo, 22°	5:45 p. m.	6:30 p. m.						
				25	Solar halo, 22°	8:10 a. m.	2:40 p. m.						
Dayton, Ohio	274	39 46	84 10	4	Solar halo, 22°	1:40 p. m.	2:00 p. m.						
				25	Solar halo, 22°	8:50 a. m.	9:05 a. m.						
				28	Solar halo, 22°	7:40 a. m.	7:55 a. m.						
Drexel, Nebr.*	396	41 20	96 16	2	Solar halo, 22°	10:39 a. m.	12:18 p. m.	10:42 a. m.	22	23	40		22
				2	Parhelion, 22°, right	10:39 a. m.	12:18 p. m.	10:43 a. m.					22
				2	Parhelion, 22°, left	10:39 a. m.	12:18 p. m.	10:44 a. m.					22
				2	Circumzenithal arc	11:26 a. m.	11:32 a. m.	11:32 a. m.			18	46	25
				5	Solar halo, 22°	1:45 p. m.	2:24 p. m.	1:51 p. m.	22	23	200		23
				5	Parhelion, 22°, right	1:45 p. m.	2:24 p. m.	1:51 p. m.			4	25	23
				5	Parhelion, 22°, left	1:45 p. m.	2:24 p. m.	1:51 p. m.			4	25	23
				5	Upper tangent arc	1:45 p. m.	2:24 p. m.	1:51 p. m.			10	23	23
				5	Solar halo, 46°	1:45 p. m.	2:13 p. m.	1:51 p. m.	46	47	100		23
				11	Solar halo, 22°	10:14 a. m.	3:00 p. m.	10:17 a. m.	22	23	180		18
				11	Lunar halo, 22°	6:00 p. m.		6:45 p. m.	22	23	360		57
				13	Lunar halo, 22°	12:15 a. m.	D. N., a. m.	1:00 a. m.			360		
				13	Solar halo, 22°	10:20 a. m.	2:30 p. m.	10:38 a. m.	22	23	80		20
				13	Solar halo, 46°	10:34 a. m.	2:05 p. m.	10:38 a. m.	45	46	180		20
				13	Circumzenithal arc	10:20 a. m.	11:45 a. m.	10:38 a. m.			15	46	20
				17	Lunar halo, 22°	10:05 p. m.	10:30 p. m.	10:15 p. m.			360		
				21	Solar halo, 22°	8:25 a. m.	9:45 a. m.	9:11 a. m.	22	23	180		11
				30	Solar halo, 22°	8:10 a. m.	8:45 a. m.	8:20 a. m.	22	23	100		6
				30	Parhelion, 22°, left	8:10 a. m.	8:45 a. m.	8:20 a. m.				22	6
Ellendale, N. Dak.*	444	45 59	98 34	1	Solar halo, 22°	12:45 p. m.	2:50 p. m.						
				1	Parhelion, 22°, right	12:50 p. m.	2:50 p. m.						
				1	Parhelion, 22°, left	12:50 p. m.	2:50 p. m.						
				1	Circumzenithal arc	12:53 p. m.	2:10 p. m.						
				2	Solar halo, 22°	11:30 a. m.	4:59 p. m.	3:00 p. m.	22	23	360		
				4	Solar halo, 22°	11:00 a. m.	2:00 p. m.	11:07 a. m.	22	23			
				4	Circumhorizontal arc	11:05 a. m.	1:10 p. m.	11:07 a. m.			40	45	
				7	Solar halo, 22°	11:45 a. m.	12:40 p. m.	11:48 a. m.	22.2	23.3			20
				10	Lunar halo, 22°	7:30 p. m.	D. N., p. m.						
				15	Lunar halo, 22°	7:20 p. m.	D. N., p. m.						
				15	Upper tangent arc	8:00 p. m.	9:20 p. m.						
				25	Lunar halo, 22°	4:30 a. m.	6:15 a. m.	5:35 a. m.	22.5	23.5	280		19.5
Groesbeck, Tex.*	141	31 30	96 28	28	Solar halo, 22°	7:48 a. m.	Sunset.	7:48 a. m.	25.5	26.5	30		4.5
				28	Solar halo, 22°	7:48 a. m.	Sunset.	9:02 a. m.	23	24.5	180		18
				28	Solar halo, 22°	7:48 a. m.	Sunset.	2:30 p. m.	22	25	360		33
Leesburg, Ga.*	85	31 47	84 14	1	Solar halo, 22°	8:10 a. m.	9:00 a. m.						
				7	Lunar halo, 22°	5:55 p. m.	8:30 p. m.	6:40 p. m.			360		
				15	Solar halo, 22°	9:05 a. m.	9:30 a. m.				200		
				15	Lunar halo, 22°	5:45 p. m.	9:30 p. m.	6:15 p. m.			220		
				16	Solar halo, 22°	2:59 p. m.	3:10 p. m.	3:08 p. m.	22	23	90		18.3
				22	Solar halo, 22°	7:28 a. m.	9:30 a. m.				30		
				26	Solar halo, 22°	3:55 p. m.	4:35 p. m.	4:00 p. m.			180		
				27	Solar halo, 22°	7:15 a. m.	4:10 p. m.	11:30 a. m.	22		180		
				28	Solar halo, 22°	7:18 a. m.	2:45 p. m.	1:10 p. m.	22	23.5	345		
				29	Solar halo, 22°	10:00 a. m.	4:00 p. m.	1:10 p. m.			360		36.5
				30	Solar halo, 22°	8:40 a. m.	1:35 p. m.	11:30 a. m.	22		360		
				31	Solar halo, 22°	8:17 a. m.	10:00 a. m.	9:00 a. m.			130		

*Aerological station.

Halo phenomena observed during January, 1919—**Continued.**

Station.	Altitude.	Latitude.		Longitude.		Date.	Form observed.	Time of— Beginning.	Time of— Ending.	Theodolite readings. Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m.	°	′	°	′						°	°	°	°	°
Madison, Wis.	297	43	05	89	23	3	Parhelion, 22°, right	8:00 a. m.	8:30 a. m.						
						3	Parhelion, 22°, left	8:00 a. m.	8:30 a. m.						
						6	Solar halo, 22°	11:45 a. m.	12:15 p. m.						
						10	Solar halo, 22°	1:30 p. m.	2:30 p. m.						
						11	Lunar halo, 22°	8:30 p. m.	8:45 p. m.						
						12	Solar halo, 22°	11:50 a. m.	1:15 p. m.						
						13	Solar halo, 22°	10:00 a. m.	2:00 p. m.						
						13	Lunar halo, 22°	6:00 p. m.	7:10 p. m.						
						14	Solar halo, 22°	1:20 p. m.	2:20 p. m.						
						18	Lunar halo, 22°	D. N., a. m.	7:00 a. m.						
						18	Solar halo, 22°	9:20 a. m.	9:30 a. m.						
						27	Solar halo, 22°	8:30 a. m.	10:00 a. m.						
						27	Parhelion, 22°, right	8:40 a. m.	8:50 a. m.						
						27	Upper tangent arc	9:50 a. m.	10:00 a. m.						
						28	Solar halo, 22°	10:55 a. m.	12:00 m.						
						28	Parhelian, 22°, right	11:30 a. m.	11:50 a. m.						
						28	Parhelian, 22°, left	11:30 a. m.	11:50 a. m.						
						30	Parhelian, 22°, right	8:40 a. m.	8:45 a. m.						
						30	Parhelian, 22°, left	8:30 a. m.	8:50 a. m.						
Nashville, Tenn	166	36	10	86	47	13	Solar halo, 22°	3:25 p. m.	3:55 p. m.						
						13	Lunar halo, 22°	6:20 p. m.	D.N., p. m.						
						15	Solar halo, 22°	6:00 p. m.	6:30 p. m.						
						16	Solar halo, 22°	8:45 a. m.	11:00 a. m.						
						31	Solar halo, 22°	9:20 a. m.	11:00 a. m.						
Royal Center, Ind.*	225	40	53	86	29	12	Solar halo, 22°	8:37 a. m.	11:15 a. m.	8:50 a. m.			200		14.5
						13	Solar halo, 22°	10:45 a. m.	11:10 a. m.	10:55 a. m.			150		
						13	Lunar halo, 22°	5:30 p. m.	D.N., p. m.	6:10 p. m.			360		
						25	Solar halo, 22°	10:30 a. m.	12:15 p. m.	11:15 a. m.			180		
						27	Solar halo, 22°	11:45 a. m.	11:50 a. m.				60		
						28	Solar halo, 22°	11:48 a. m.	12:10 p. m.	11:55 a. m.			180		
						30	Solar halo, 22°	11:35 a. m.	12:00 m.	11:43 a. m.	22		200		31
						30	Parhelion, 22°, right	11:20 a. m.	12:00 m.	11:43 a. m.			10	25	31
						30	Parhelion, 22°, left	11:23 a. m.	12:00 m.	11:43 a. m.			10	25	31
Tatoosh Island, Wash	26	48	23	124	44	7	Solar halo, 22°	10:58 a. m.	12:18 p. m.						
						7	Parhelion, 22°, right	11:37 a. m.	11:54 a. m.						
						7	Parhelion, 22°, left	11:50 a. m.	12:18 p. m.						
						8	Solar halo, 22°	8:50 a. m.	9:45 a. m.						
						8	Lunar halo, 22°	7:33 p. m.	7:36 p. m.						
						9	Solar halo, 22°	12:10 p. m.	12:25 p. m.						
						9	Lunar halo, 22°	7:05 p. m.	D.N., p. m.						
						19	Solar halo, 22°	2:30 p. m.	2:50 p. m.						
						19	Parhelion, 22°, right	3:20 p. m.	3:26 p. m.						
						20	Lunar halo, 22°	5:03 a. m.	6:25 a. m.						
						20	Lunar halo, 46°		6:00 a. m.						
						20	Upper tangent arc		6:00 a. m.						
						20	Solar halo, 22°	8:32 a. m.	10:40 a. m.						
						20	Parhelion, 22°, right	8:32 a. m.	9:50 a. m.						
						20	Parhelion, 22°, left	9:10 a. m.	9:50 a. m.						
						21	Solar halo, 22°	9:20 a. m.	12:20 p. m.						
						23	Solar halo, 22°	3:05 p. m.	4:05 p. m.						
						23	Solar halo, 46°	3:18 p. m.	3:25 p. m.						
						24	Lunar halo, 22°	6:26 a. m.	6:34 a. m.						
						24	Solar halo, 22°	9:56 a. m	10:40 a. m						
						24	Upper tangent arc	10:28 a. m	10:32 a. m						
						26	Solar halo, 22°	1:41 p. m	1:43 p. m						
						28	Solar halo, 22°	3:50 p. m	4:04 p. m						
						28	Light pillar	5:15 p. m	5:30 p. m						
						29	Solar halo, 22°	8:40 a. m	5:05 p. m						
						29	Parhelion, 22°, right	8:40 a. m	4:33 p. m						
						29	Parhelion, 22°, left	8:40 a. m	4:40 p. m						
						29	Upper tangent arc	4:18 p. m	4:33 p. m.						
						29	Solar halo, 46°	2:40 p. m.	2:45 p. m.						
						29	Circumzenithal arc	2:40 p. m.	2:45 p. m.						
						29	Light pillar	5:05 p. m.	5:15 p. m						
York, N. Y	232	42	52	77	53	4	Solar halo, 22°	4:30 p. m.	4:35 p. m.						
						12	Lunar halo, 22°	6:35 p. m.	9:20 p. m.	7:15 p. m.			360		
						12	Lunar halo, 46°			7:30 p. m.			90		
						15	Solar halo, 22°	9:25 a. m.							
						16	Lunar halo, 22°	8:15 p. m.	8:45 p. m.	8:20 p. m.			30		
						18	Solar halo, 22°			3:30 p. m.					
						22	Lunar halo, 22°			2:20 a. m.			30		

*Aerological station.

Halo phenomena observed during January, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness	Clouds. Amount.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Broken Arrow, Okla*	3	R, Y	Bright				Rising	3:15 p. m., 1st	5:00 p. m., 4th.
	3		Bright						
	3		Bright						
	4		Dim	1	A. st.	nw.	Falling	3:15 p. m., 1st	5:00 p. m.. 4th.
	10	R	Dim	6	Ci.	n.	Falling	7:10 p. m., 4th	D. N., p., 13th.
	11		Dim	6	Ci. st.	n.	Stationary	7:10 p. m., 4th	D. N., p., 13th.
	13	R	Bright	10	Ci. st.	w.	Rising	7:10 p. m., 4th	D. N., p., 13th.
	15	R	Dim	3 4	Ci. st. A. st.	wsw. ssw.	Falling	D. N., a., 14th	D. N., a., 16th.
	15		Dim	8	A. st.	w.	Falling		
	24	R	Dim	10	Ci. st.	sw.	Stationary	12:10 p. m., 20th	D. N., a., 27th.
	25	Y	Dim	7	Ci. st.	sw.	Rising.	12:10 p. m., 20th	D. N., a., 27th.
	25	R	Dim	3 7	Ci. st. A. st.	sw. sw.	Rising		
Canton, N. Y	6	R, O	Dim	2	Ci. st.	w.	Falling	8:00 a. m., 4th	8:00 p. m., 7th.
	22	R, O	Dim	3	Ci. st.	w.	Falling	8:00 p. m., 19th	8:00 p. m., 22d.
	28	R, O	Dim	3	Ci. st.	w.	Falling	8:00 p. m., 27th	
Cincinnati, Ohio	7	R, O, Y	Dim	6	Ci. st.	w.	Falling	10:40 a. m., 6th	12:54 p. m., 7th.
	13		Dim	8	Ci. st.	w.	Stationary	12:15 p. m., 9th	1:30 a. m., 14th.
	25	R, O, Y, G, B	Bright	10	Ci. st.	w.	Falling	11:35 a. m., 23d	6:44 a. m., 3d.
Dayton, Ohio	4		Dim	6	Ci. st.	nw.	Stationary	8:30 p. m., 3d	8:30 p. m., 5th.
	25		Dim	5	Ci. st.	w.	Stationary	12:45 p. m., 23d	
	28		Dim	6	Ci. st.	nw.	Falling	12:45 p. m., 23d	
Drexel, Nebr.*	2	R, O, G	Dim	1	St.	nw.	Rising	11:30 p. m., 31st	2:30 p. m., 2d.
	2	R, O, G	Bright	1	St.	nw.			
	2	R, O, G	Bright	1	St.	nw.			
	2	R, O, G	Dim	4	St.	nw.			
	5	O, Y, G, B	Bright	2	Ci. st.	nw.	Falling	7:50 p. m., 4th	D. N., a., 7th.
	5	O	Bright						
	5	O	Bright						
	5	O	Dim						
	5	O, Y, G, B	Dim						
	11		Dim	7	Ci. st	w.	Stationary	2:30 p. m., 7th	7:58 a. m., 22d.
	11		Bright	10	Ci. st.	w.	Stationary		
	13		Bright	10	Ci. st.	wsw.	Rising	2:30 p. m., 7th	7:58 a. m., 22d.
	13	O, Y, G, B	Dim	10	Ci. st.	wsw.	Stationary.		
	13	O, Y, G, B	Dim						
	13	R, G, B	Bright						
	17		Dim	10	Ci. st.	nw.	Stationary	2:30 p. m., 7th	7:58 a. m., 22d.
	24	R, O, Y, G, B	Dim	10	Ci. st.	wsw.	Stationary.	11:00 a. m., 22d	3:50 p. m., 1st.
	30	O	Dim	4	Ci. st.	nw.	Rising	11:00 a. m., 22d	3:50 p. m., 1st.
	30	O	Bright						
Ellendale, N. Dak.*	1	R	Bright				Falling	10:20 a. m., 1st	1:50 p. m., 3d.
	1								
	1								
	1	R	Bright						
	2	R	Brilliant				Rising	10:20 a. m., 1st	1:50 p. m., 3d.
	4	R	Brilliant				Rising	10:00 a. m., 4th	4:45 p. m., 6th.
	4	R	Brilliant						
	7	R	Dim	6	Ci. st.		Falling	5:40 p. m, 6th	9:15 a. m., 13th.
	10		Bright	7	Ci. st	nw.	Stationary	5:40 p. m., 6th	9:15 a. m., 13th.
	15	R	Bright				Falling	9:50 a. m., 13th	5:05 p. m., 21st.
	15	R	Bright						
	25			4	Ci. st.	wnw.	Rising	11:20 a. m., 22d	4:15 p. m., 2d.
Groesbeck, Tex.*	28	R, O, Y, G, B	Bright	6	Ci. st.	wsw.	Rising	D. N., a., 22d	12:08 p. m., 1st.
	28	R, O, Y, G, B	Bright	7	Ci. st.	wsw.	Rising		
	28	R, Y, B	Bright	8	Ci. st.	wsw.	Stationary		
Leesburg, Ga.*	1	R, O	Dim	2	Ci. st.		Stationary	4:00 p. m., 31st	D. N., a., 2d.
	7			10	A. st.	w.	Falling	D. N., p., 2d	D. N., a., 8th.
	15	R, O	Dim	2	Ci. st.	w.	Stationary	D. N., a., 14th	8:23 a., 16th.
	15	R	Dim	8	A. st.	w.	Rising		
	16	R, O, G	Bright	8	Ci. st.	w.	Falling	8:28 a. m., 16th	9:40 p. m., 16th.
	22			6	Ci. st.	nw.	Rising	3:30 p. m., 17th	3:35 p. m., 22d.
	26	R, O	Dim	Few.	Ci.	w.	Rising	D. N., a., 26th	5:20 p. m., 2d.
	27	R, O	Dim	7	Ci. st.	nw.	Falling	D. N. a., 26th	5:20 p. m., 2d.
	28	R, O, G	Bright	8	Ci. st.	w.	Stationary	D. N., a., 26th	5:20 p. m., 2d.
	29	R	Dim	7	Ci. st.	wnw.	Falling	D. N., a., 26th	5:20 p. m., 2d.
	30	R	Dim	4	Ci. st.	w.	Stationary	D. N., a., 26th	5:20 p. m., 2d.
	31			9	A. st.	w.	Stationary	D. N. a., 26th	5:20 p. m., 2d.
Madison, Wis.	3	R	Brilliant	8	A. cu.	nw.	Stationary	7:30 a. m., 3d	8:00 p. m., 4th.
	3	R	Brilliant						
	6		Dim	9	A. st.	s.	Falling	11:30 a. m., 6th	8:30 a. m., 7th.
	10	R	Bright	8	Ci. st.	w.	Stationary.	4:00 p. m., 7th	2:45 p. m., 18th.
	11		Dim	10	Ci. st.	w.	Stationary	4:00 p. m., 7th	2:45 p. m., 18th.
	12	R	Bright	9	A. st.	sw.	Falling	4:00 p. m., 7th	2:45 p. m., 18th.
	13	R	Dim	10	Ci. st.	w.	Stationary	4:00 p. m., 7th	2:45 p. m., 18th.
	13		Dim	7	Ci. st.	w.	Stationary		
	14	R, O	Bright	10	Ci. st.	w.	Stationary	4:00 p. m., 7th	2:45 p. m., 18th.
	18		Dim	10	Ci. st.	w.	Rising	4:00 p. m., 7th	2:45 p. m., 18th.
	18	R, O, B	Brilliant	9	Ci. st.	w.	Rising		
	27	R	Dim	6	Ci. st.	w.	Rising	3:00 p. m., 18th	10:05 a. m., 3d.
	27	R	Dim	6	Ci. st.	w.			
	27	R	Bright	3	Ci. st.	w.			
	28		Dim	10	Ci. st.	w.	Stationary	3:00 p. m., 18th	10:05 a. m., 3d.
	28		Dim						
	28		Dim						
	30	R	Brilliant	1	Ci. st.	w.	Stationary	3:00 p. m., 18th	10:05 a. m., 3d.
	30	R	Brilliant						
Nashville, Tenn	13	O	Dim	8	Ci. st.	w.	Falling	D. N., p., 7th.	6:15 a. m., 14th.
	13		Bright	8	Ci. st.	w.	Falling		
	15		Dim	6	Ci. st.		Stationary	7:45 p. m., 14th	3:15 p. m., 16th.
	16	R, O, Y	Dim	10	Ci. st.	w.	Stationary	7:45 p. m., 14th	3:15 p. m., 16th.
	31	R, O, Y	Dim	8	Ci. st.	w.	Stationary	10:00 a. m., 23d	3:00 p. m., 2d.
Royal Center, Ind.*	12		Dim	8	Ci. st.	w.	Stationary	6:00 p. m., 9th	D. N., a., 23d.
	13		Dim	8	Ci. st.	w.	Falling	6:00 p. m., 9th	D. N., a., 23d.
	13	R, O, Y, B	Bright	10	Ci. st.	w.	Stationary		
	25	R, O, Y, B	Dim	7	Ci. st.	w.	Falling	7:15 a. m., 23d	7:18 a. m., 3d.
	27		Dim	8	Ci. st.	w.	Falling	7:15 a. m., 23d	7:18 a. m., 3d.
	28	R, B	Dim	4	Ci. st.	w.	Falling	7:15 a. m., 23d	7:18 a. m., 3d.
	30	R, O, Y, G, B	Dim	7	Ci. st.	w.	Stationary	7:15 a. m., 23d	7:18 a. m., 3d.
	30	R, O, Y, G, B	Bright						
	30	R, O, Y, G, B	Bright						

*Aerological station.

† Beginning with part nearest sun or moon. R, red; O, Orange, etc.

Halo phenomena observed during January, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds. Amount.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Tatoosh Island, Wash.	7	O	Dim	2	Ci.	nw.	Rising	D. N., a., 6th	D. N., a., 10th.
	7	R, O, Y, G	Dim						
	7	R, O, Y, G, V	Dim						
	8	O	Dim	2	Ci. st.	w.	Rising	D. N., a., 6th	D. N., a., 10th.
	8	O	Dim						
	9	O	Dim	10	A. st.	s.	Falling	D. N., a., 6th	D. N., a., 10th.
	9	O	Dim	10	A. st.	s.	Falling	D. N., a., 6th	D. N., a., 10th.
	19	O	Dim	6	Ci.	w.	Rising	12:30 p. m., 19th	2:15 p. m., 20th.
	19	R, B	Dim	2	Ci.	w.			
	20	O	Dim	2	Ci.	sw.	Falling	12.30 p. m., 19th	2:15 p. m., 20th.
	20		Dim						
	20		Dim						
	20	R, B	Dim	5	Ci.	sw.	Rising		
	20	R, O, G, B	Bright						
	20	R, O	Dim						
	21	R	Dim	3 6	Ci. A. cu.	w. s.	Stationary	5:02 a. m., 21st	6:31 p. m., 21st.
	23	R, O, Y, G	Bright	4	A. st.	wsw.	Rising	2:55 p. m., 23d	4:52 p. m., 23d.
	23	O	Dim						
	24	R, B	Bright	1	A. st.	wsw.	Falling	D. N., p., 23d	6:55 a. m., 24th.
	24	O	Dim	8	A. st.	sw.		9:50 a. m., 24th	10:50 a. m., 24th.
	24	O	Dim						
	26	Y	Dim	9	A. st.	w.	Falling	1:40 p. m., 26th	3:35 p. m., 26th.
	28	O	Dim	6	Ci.	sw.	Rising	2:20 p. m., 28th	7:36 a. m., 30th.
	28	Y	Bright	1	Ci.	w.		2:20 p. m., 28th	7:36 a. m., 30th.
	29	R, O, B	Bright	8	Ci. st.	wnw.	Stationary		
	29	R, O, B	Dim						
	29	R, B	Dim						
	29	O	Dim	6	Ci. st.	w.			
	29	O	Dim	7	Ci. st.	wnw.			
	29	O	Dim						
	29	Y	Dim	5	Ci.	w.			
York, N. Y.	4	R, O	Dim	1	St. cu.	sw.	Rising	2:00 p. m., 3d	10:00 a. m., 8th.
	12		Bright	8	Ci. st.	w.	Falling	5:00 p. m., 10th	5:30 p. m., 14th.
	12		Dim						
	15			8	Ci. st.	w.	Stationary	12:00 m., 11th	11:00 a. m., 15th.
	16	R	Dim	10	Ci. st.	sw.	Falling	5:00 p. m., 15th	7:00 a. m., 19th.
	18						Rising	5:00 p. m., 15th	7:00 a. m., 19th.
	22		Dim	10	St. cu.	sw.	Stationary	D. N., p., 21st	11:00 a. m., 23d.

*Aerological station.

† Beginning with part nearest sun or moon. R, red; O, Orange, etc.

NOTES.

Drexel, Nebr.—On January 2, halo phenomena were observed with only low-lying clouds present. The altitude of these clouds, as determined during kite flights, was about 1,700 meters. Temperatures at the surface were about −20° C. and at the altitude of the cloud layer, about −30° C. Although recorded as stratus, these clouds were probably composed of ice spicules, and therefore might have been designated "cirro-stratus," or, even better, be given a special name, since stratus clouds are usually thought of as dense, low-lying, and composed of water droplets, and cirro-stratus, as thin, high and icy.

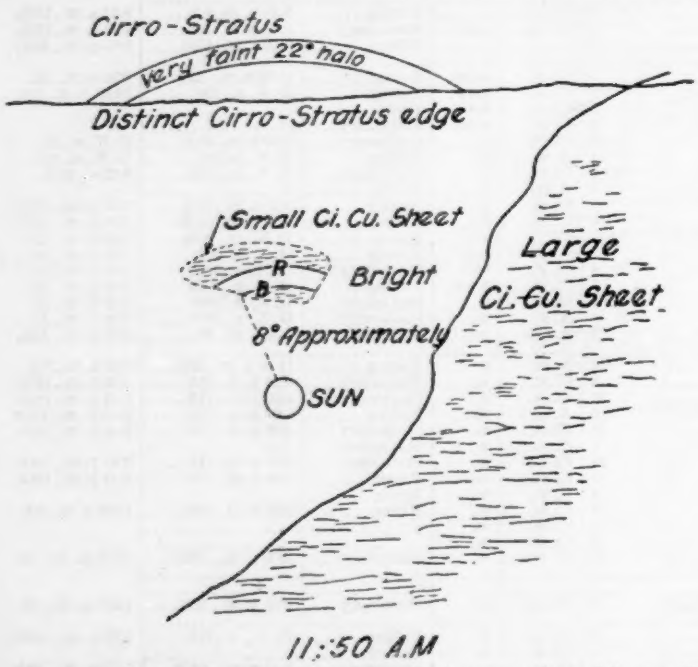


FIG. 1. Simultaneous formation of solar halo and solar corona observed January 27, 1919, at Royal Center, Ind.

Some discussion of halos formed under conditions similar to those above given may be found in Monthly Weather Review Supplement No. 12 (Aerology No. 7), p. 5.

Groesbeck, Tex.—A solar halo was observed throughout the day on January 28. Interesting variations were noted in the inner and outer radii, the former diminishing from 25.5° to 22° and the latter from 26.5° to 25°.

Leesburg, Ga.—The solar halo observed on the 29th had a vertical radius of 22° and a horizontal radius of 26¼°. The measurements were made at 1:10 p. m., with a solar altitude of 36½°. Probably, therefore, the phenomenon observed was a circumscribed halo.

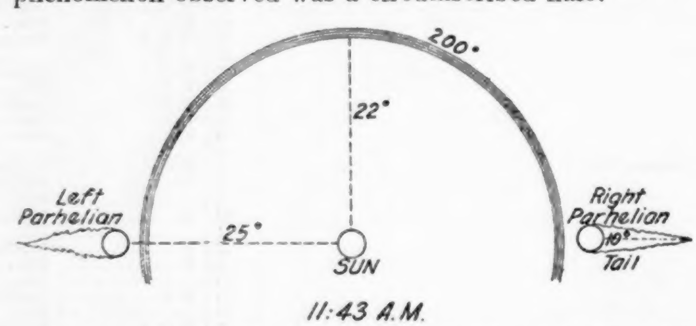


FIG. 2. Solar halo and well-developed parhelia observed January 30, 1919, at Royal Center, Ind.

Royal Center, Ind.—On January 27th there was a simultaneous occurrence of arcs of an 8° corona and a 22° halo, the former being due to Ci. Cu. clouds near the sun. These clouds were highly colored, the predominating colors being blue and violet. A sketch is shown in figure 1.

Unusually well developed parhelia were observed on January 30. See figure 2.

Beginning with this month two new stations are added to the list, viz., Tatoosh Island, Wash., R. C. Mize, Observer, and York, N. Y., Milroy N. Stewart, Cooperative Observer. Mr. Stewart's observations are made partly at York and partly at Rochester, N. Y.

SIMULTANEOUS OCCURRENCES OF LUNAR HALOS AND CORONAS.

By C. F. BROOKS, Meteorologist.

[Dated: Weather Bureau, Washington, Mar. 5, 1919.]

The simultaneous occurrence of a lunar halo and corona is not such a rarely observed phenomenon as that of a solar halo and corona, for the brilliance of the sun is adverse to frequent observation of the solar corona. The following note appeared in Meteorological Office Circular.[1] (London) 21, February 26, 1918, page 3:

> Capt. C. J. P. Cave writes from Stonehenge: "A halo and a corona around the moon were visible here at 11 p. m. on February 21. Rippled clouds had come up from the northwest about 6:15 p. m. and the beginning of a halo had been seen when they reached the neighborhood of the moon; before 7:30 the rippled appearance had disappeared, but the sky was covered with a thin sheet of cirro stratus, through which the brighter stars could be seen; a very striking halo was visible from this time till 11 p. m. About this time a corona also became visible, two red rings being seen. Almost at the same time part of the halo was hidden by low clouds, and in a few minutes these drifted over, and both halo and corona disappeared. The phenomenon was very striking and must be very rare; two thin cloud sheets are necessary for its production; the upper one must be sufficiently thin to allow enough light to pass through to produce a corona, and the lower sheet must be thin enough not to hide the halo; moreover the moon must be of sufficient age to be bright enough for the phenomenon to be seen."

Capt. Cave's conclusion does not seem to apply in two recent observations of mine. At College Station, Tex., September 18, 1918, I made the following note: "At 10 p. m. [90th Meridian 'Summer' time] there was a colored, large, double corona (due to the water-drop A.Cu. clouds), a fine, unbroken halo (due to the snow falling from the A.Cu.), and an annulus (due to the raindrops formed from the melting snow)." On February 12, 1919, at Washington, D. C., I have this note: "At 10:20 [p. m. 75th Meridian Time] the high clouds [Ci.St. and Ci.Cu.] had thinned appreciably and the halo had become bright colored. There was a corona (single ring, radius about 3°) at the same time." In this case, also, the water-drop clouds seem to have been above or in the falling snow which produced the halo, for the texture of the Ci.Cu. elements of the general cloud sheet were indistinct. In both cases the moon was two days before full.

Thus, it seems that another explanation for the simultaneous occurrence of halo and corona is, that the halo forms in a sheet of snow which is falling out of, or through, clouds of (undoubtedly undercooled) water drops, or spheres of clear ice,[2] and that when an annulus is observed with a halo, there is every reason to believe that the falling snow crystals which make up the Ci.St. sheet are reaching a level where they are melting into fine raindrops.

LUNAR HALO AND PARASELENIC CIRCLE OBSERVED AT COLONY, WYO.

Through the official in charge at Cheyenne, Wyo., Mr. Cola W. Shepard, Cooperative Observer, reports that a lunar halo and a paraselenic circle were observed at Colony, Wyo., on January 10, 1919. Both circles were complete and very distinct. They were brightest at about 9 p. m., but had been visible for some time before this.—*W. R. G.*

[1] The British Meteorological Office Circular is primarily a means of communication between the office and observers. It is an octavo leaflet of 4 pp. issued monthly since June, 1916.

[2] Cf. G. C. Simpson, Coronae and Iridescent Clouds, Quart. Jour. Roy. Met. Soc., Oct., 1912, vol. 38; and recent discussions in Symons's Met. Mag., 1917, vol. 52, by Simpson, pp. 17-18, and E. C. Barton, pp. 31-32.

NOTES ON THE COMPARISON OF ANEMOMETERS UNDER OPEN-AIR CONDITIONS.*

By A. NORMAN SHAW

[Dated: McGill University, Montreal, Quebec, Feb. 8, 1919.]

CONTENTS.

Section 1. Introduction.—The comparison of anemometers has occupied considerable attention especially since the rapid development of aeronautics, and the accuracy of the ordinary instruments is fairly well known. There has, however, been occasional difficulty in correlating tests and calibrations made under the controlled conditions of the "wind tunnel" or the "whirling table," with the practical usage of the instruments in fluctuating open-air conditions. The electrical or "hot-wire" anemometer[1] and the kata-thermometer[2] as an anemometer do not appear yet to have received the extensive application for which they are apparently fitted, and very little attention seems to have been directed toward their adaptation for use under open-air conditions.

It is the object of these notes to discuss some observations of possible interest in this connection, which were taken at Father Point Experimental Station in September and October, 1917, during the acoustic surveys of Dr. L. V. King. Meteorological observations[3] were required in order that the influence of atmospheric structure on the propagation of sound might be studied, and through the kind permission of Sir Frederick Stupart, director of the Dominion meteorological bureau, Mr. J. Patterson of that department joined Dr. King's party and brought with him a supply of standard meteorological instruments and accessories. It was in association with Mr. Patterson at this time that the present writer became interested in these instruments.

The hot-wire anemometer tests were made at the suggestion of Dr. King, with his recently developed portable outfit which had been brought down to the experimental station.

The kata-thermometer was in use by the writer for some humidity investigations, and when this opportunity presented itself it was thought of interest to test the claims of the designers with reference to its application as an anemometer.

It should be pointed out that these notes are the result of observations incidental to another investigation and consequently they are somewhat incomplete, but as the comparisons were not continued it was thought that they were of sufficient interest to be recorded with this explanation.

* These notes were made in connection with work performed under the auspices of the Honorary Advisory Council for Scientific and Industrial Research in Canada, who very kindly gave permission for their publication.

[1] See L. V. King, "The linear hot-wire anemometer and its applications in technical physics," Jour. Frank. Inst., Jan., 1916, pp. 1-25, where a complete list of references is given. Also J. S. G. Thomas, "Hot-Wire Anemometry," Sci. Am. Sup., Feb. 15, 1919, (pp. 106-107); and T. S. Taylor, "A new type of hot-wire anemometer," abs. Phys. Rev. (2nd Ser.) xiii, Feb., 1919 (pp. 146-147).

[2] Hill, Griffith and Flack, "The measurement of the rate of heat-loss at body temperature by convection, radiation, and evaporation," Phil. Trans. Roy. Soc. London, B., vol. 207, p. 201 (1915).

[3] The meterological observations are discussed by Mr. J. Patterson and the present writer in sections of Dr. L. V. King's Report to the Honorary Advisory Council of Scientific and Industrial Research, on "The acoustic efficiency of fog-signaling, Father Point experiments, 1917."

Section 2. The Robinson cup anemometer compared with pilot balloons under open-air conditions.—A comparison between the values of wind velocities determined with a Robinson cup anemometer and those calculated from observations on a pilot balloon drifting past it is of interest as a check calibration under conditions of practical usage.

The pilot balloons, which were employed in these tests, consisted of thin rubber envelopes filled with pure hydrogen, and had a dead weight of about 3 grams and a free lift of about 8 grams. They rose, when released, with a velocity of approximately 80 meters per minute. Observations on their movements were made with a theodolite at the end of each successive minute after their release.

Table 1 gives a comparison between the average horizontal velocities calculated for the first minutes of their respective ascents and the velocities as determined from the Robinson cup anemometer on the top of the standard 40-foot meteorological tower at Father Point. The readings are recorded only for cases when the balloons moved during the first minute in an approximately straight line and when there was a negligible velocity gradient in that interval.

The calculation of the velocities and the directions were made from the theodolite readings by the formulae

$$V_1 = h_1 \cot c_1 \text{ and } \theta_1 = a_1 + b,$$

where V_1 is the average velocity during the first minute; h_1 is the height at the end of the first minute; c_1 is the angle of elevation; θ_1 is the "true bearing"; a_1 is the azimuth reading; and b is the correction necessary to reduce the theodolite readings for a to true bearings.[4]

The Robinson cup readings were obtained from the standard instrument and records at the meteorological station. The recorder gave the value of the wind equal to three times the velocity of the cups. This was corrected by Marvin's formula,

$$\log V = .079 + .901 \log v,$$

where V is the velocity of the wind, and v is *three times* the velocity of the centers of the cups each expressed in miles per hour.[5]

TABLE 1.—*Comparison between Robinson cup and pilot balloon observations under open-air conditions.*

Date.	Robinson cup at elevation of 40 feet (corrected values).		Pilot balloon average up to elevation of approximately 260 feet.	
	Mi./hr.	*Dir.*	*Mi./hr.*	*Dir.*
Sept. 15, 4.30 p. m.	8	NE.	8	NE.
18, 4.00 p. m.	9	W.	10	W.
20, 3.20 p. m.	16	NE.	16	NE.
22, 1.50 p. m.	16	NE.	14	NE.
26, 10.17 a. m.	11	SW.	18	SW.
Oct. 3, 10.20 a. m.	21	SW.	21	SW.
5, 1.42 p. m.	10	W.	10	W.
10, 2.06 p. m.	16	NE.	16	NE.
10, 3.31 p. m.	14	NE.	14	NE.

[4] The general expressions for V_n and θ_n, respectively, the velocity and direction during the nth minute after release, are:

$$V_n = \{(h_{n-1} \cot c_{n-1})^2 + (h_n \cot c_n)^2 - 2 h_{n-1} h_n \cot c_{n-1} \cot c_n \cos (a_n - a_{n-1})\}^{1/2}, \text{ and}$$

$$\theta_n = \sin^{-1}\left\{\frac{h_n \cot c_n \sin (a_n - a_{n-1})}{V_n}\right\} + a_{n-1} + b.$$

If it is desired to consider the whole course of the balloon it is, however, easier to determine the values of V and θ by making a plan of the path of the balloon from the projections of its positions, and then obtaining the successive values graphically from it.

[5] For a description of this standard outfit which is similar to that adopted by the Weather Bureau in the United States, see "Instructions for the installation and maintenance of wind measuring and recording apparatus" Circular D, instrument division, Weather Bureau, U. S. Dept. of Agriculture.

The letters N, S, E, and W refer in the customary manner to the direction *from* which the wind blows. There was no general agreement closer than the nearest mile per hour as given. Each determination of the balloon values was made as in the following sample case:

Sept. 15, 4.30 p. m.—Theodolite readings:

$$a_1 = 135° \text{ and } b = 102°$$
$$c_1 = 21.1° \quad h_1 = 260 \text{ feet.}$$

hence $V_1 = h_1 \cot c_1 = 8$ mis./hr. approximately; and $\theta_1 = a_1 + b = 237°$; therefore 57° is the bearing of the direction from which the wind was blowing, which we may call NE., as the standard wind vane recorded the compass directions only to eight points; the value of b was determined by a theodolite comparison of the bearing of the Father Point Lighthouse with that of the pole star; the value of h_1 was determined from Hergessel's curves from the ascent velocity of small spherical balloons filled with hydrogen, expressed in terms of the dead weight and the free lift.[6]

There was at first some doubt about the interpretation of these curves and the formula which they represent, for balloons as small as those used, especially as the use of Dines's formula, gave a slightly different value for the ascent.[7] This was, however, checked by a comparison with the results obtained with a larger balloon having a free lift of about 100 g. and a dead weight of about 30 g. The assumption of 80 meters per minute for the smaller balloons gave approximately the same results for the wind velocities at given heights as were calculated by means of the larger balloons for which Hergessel's and Dines's formulae agreed.[8]

Section 3. The Robinson cup anemometer compared with a simple Pitot tube anemometer under open-air conditions.—A comparison of the Robinson cups and the Pitot tube under open-air conditions, was undertaken in connection with tests on a simple but sensitive form of Pitot tube which was required for the acoustic surveys. It was desired to test the suitability of the tube for the indication of gustiness, and as a preliminary it was compared with a Robinson cup anemometer which had been standardized.

Two Pitot tubes were employed, and each consisted of a U tube of about 8 mm. internal diameter, with its ends bent both in the same direction at right angles to, and in the same plane as, the U part. One end was open and the other was tipped with a *polished* brass cylinder having a closed conical end. Around the side of the cylinder were six small holes each slightly less than a millimeter in diameter. The U was half filled with gasoline and was mounted on a stand which could be tilted to any desired angle in order to increase the sensitiveness for low velocities.

It is now generally accepted that the formula

$$V^2 = 2P/\rho$$

deduced for this type of Pitot tube from Bernoulli's theorem for stream line motion in fluids—where V is the velocity of the wind, P the pressure (in absolute units of force) on the open side, and ρ the density of the air—may be applied in the interpretation of the observations.[9]

[6] Hergessel, Sixième Reunion de la Commission Internationale pour l'Aerostation Scientifique, 1909.

[7] The formula $V^6 = kL^3/W^2$ where V is the velocity, k a constant, L the free lift and W, the weight. Dines's, Meteor. Oft. London Pub. M. O. 202, p. 27.

[8] A discussion of American methods of reducing pilot-balloon observations will appear in an early issue of the REVIEW.—ED.

[9] Hunsaker, "The Pitot tube and the inclined manometer," Smithsonian Publication No. 2368, p. 27 (1916); Bramwell and Page, "On the determination of the pressure-velocity constant for a Pitot (velocity-head and static-pressure) tube," Tech. Rep. of the Adv. Com. for Aeronautics (Brit.), 1912-13, p. 35; Rowse, "Pitot tubes for gas measurements," Pro. Am. Soc. Mech. Eng., April, 1913, p. 640.

The alteration of this formula to suit our particular readings is a simple matter.

Let v = the velocity in miles per hour.[10]

r = the reading in cm. of the gasoline on one side of the tube, i. e., the distance from the scale zero. Thus the "head" = $2r$.

d = the density of the gasoline in grams per cc.

g = the gravitational acceleration constant in cm. per sec. per sec.

A = the angle of slope of the stand in degrees.

ρ = the density of the air in grams per cc.

Substituting in the above formula and multiplying by the required constants in order to express v in mi./hr., we get—

$$v^2 = 0.00200 \frac{r\,d\,g\,\sin A}{\rho}$$

In our case $d = 0.75$ gm./cc., $g = 980$ cm./sec.², $\sin A = 1.32$, and $\rho = 0.00129$ gm./cc.[11], hence the formula reduced to

$$v^2 = 151\,r$$

In the same way formulae could be deduced for any particular slopes and densities. The two Pitot tubes were used in the comparisons, and the average readings for them during successive half-minute periods are given in the second column of Table 2. The method of averaging is discussed in the paragraphs following the table. The velocities given in the next column are calculated from these by the formula given. The two tubes were compared previously, in a fluctuating wind, and the tops of the corresponding liquid columns in each tube were found to keep very closely in line. Occasionally the free period of vibration of the gasoline affected the readings momentarily by as much as 1 cm., but this was infrequent and was apparently quickly damped. It was thought that damping devices could readily be introduced which would eliminate this entirely.

In the fourth column of the table the velocities as determined from the Robinson cups are given. The cups were mounted near the tubes, and the recording attachment was arranged to tick off on a chronograph every quarter of a mile of wind. The average value of the wind during each half minute was measured off afterwards from the chronogram and corrected by Marvin's formula.

In the last column of the table the constant of the Pitot tubes is given as calculated in each case independently in terms of the Robinson cup values, with the satisfactory average result shown. It is somewhat of an inversion to express an absolute method of measurement in terms of an empirical one, but it was of interest here to determine the constant of our Pitots in terms of a standardized instrument.

[10] "Miles per hour" was considered more convenient than "meters per sec." because the accuracy of the results was of the order of 1 mi./hr., and these units were also more convenient in other parts of the investigation.

[11] The average density ρ was calculated from the formula for moist air

$$\rho = 0.00464\,(B - 0.378\,p)/T$$

where B = the barometric reading in mm., p = the atmospheric aqueous vapor pressure in mm., and T = the absolute temperature. On the occasion of the observations recorded here, B = 770 mm., T = 275° A, and p = 4.05 mm. B was obtained from the near-by meteorological station, and T and p were determined with standard instruments at the place of observation, the average being taken of readings obtained before, during, and after the tests.

TABLE 2.—*Comparison between Robinson cup and Pitot tube observations under open-air conditions.*

Observations.	Average reading of Pitot tube during half a minute. (r)	Average velocity of wind. ($v^2=151r$)	Average velocity of wind during the half minute, determined by Robinson cup. (V)	Constant for Pitot tube as determined from standardized Robinson cup readings. $\left(\frac{V^2}{r}\right)$
	Cm.	*Mi./hr.*	*Mi./hr.*	
	(Pitot No. 1)			
1	2.8	21	21	157
2	3.1	22	22	156
3	2.7	20	19	134
	(Pitot No. 2)			
4	2.6	20	20	154
5	2.6	20	20	154
6	2.6	20	21	170
7	2.6	20	21	170
8	2.5	19	19	145
9	2.6	20	19	139
	(Pitot No. 1)			
10	2.1	18	19	171
11	2.2	18	18	147
12	2.4	19	18	135
13	2.0	17	17	145
14 [1]	0-0.2	0-5.5	3	
Mean				152±2.4 [2]

[1] This observation was taken at a different time.

[2] It was thought that the "probable error," ±2.4, could be mentioned reasonably, even with only 13 observations, because there are just as many Robinson cup readings above as below the mean, and the probable error of any one reading is less than 6 per cent (±8.6). (Bessel's formula was used.)

Section 4. Notes on the use of a simple Pitot tube for the analysis of gustiness.—It was somewhat difficult to get the average Pitot reading during half a minute, as the movements of the gasolene were sometimes momentarily erratic and rapid. As the gusts were approximately periodic the following method was adopted: The maximum and minimum readings during the half minute were recorded and their mean taken, also the mean position of the liquid was estimated by another observer and the mean of the two results was taken as representing approximately the average reading. The figures in Table 3 show the variations obtained in the case of the observations for the Pitots in Table 2; they give an indication of the sensitiveness of the instrument to fluctuations and show that it could readily be adapted to the study of gustiness.

TABLE 3.—*Fluctuations of the Pitot tube readings during the half-minute intervals.*

Observations.	Maximum reading.	Minimum reading.	Average of maximum and minimum.	Estimated mean reading.	Final mean. (r)	Average velocity. ($v^2=151r$)
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Mi./hr.*
1	5.0	1.2	3.1	2.5	2.8	20.6
2	5.0	1.5	3.2	3.0	3.1	21.6
3	4.0	1.4	2.7	2.7	2.7	20.2
4	4.2	0.8	2.5	2.7	2.6	19.8
5	4.5	1.0	2.8	2.4	2.6	19.8
6	3.5	1.1	2.3	2.8	2.55	19.6
7	4.0	0.9	2.4	2.8	2.6	19.8
8	3.5	0.9	2.2	2.8	2.5	19.4
9	4.0	1.2	2.6	2.6	2.6	19.8
10	3.0	1.0	2.0	2.2	2.1	17.8
11	3.0	0.6	1.8	2.5	2.15	18.0
12	4.0	1.0	2.5	2.3	2.4	19.0
13	3.2	1.0	2.1	2.0	2.05	17.6

It will be seen that in several cases the estimated mean readings are higher than the average of the maximum and minimum, but it must be understood that the accuracy of estimation and the magnitude of the fluctuations due to occasional free vibration, were sufficient to cause discrepancies of this kind, and the two determinations of the mean were made only for the purpose of obtaining a more reliable final mean.

Comparing the mean gust velocity calculated from the maximum readings (viz, 24.2 mis./hr.) and the mean lull velocity calculated from the minimum readings (viz, 12.5 mi./hr.) with the mean of the Robinson cup readings (viz, 19.6 mi./hr.) we get for the period of our test that the mean gust velocity is equal to 1.23 v, and that the mean lull velocity is equal to 0.65 v where v is the mean velocity determined from the standardized cups. The extreme gust velocity was 1.4 v and the extreme lull velocity (with the exception of observation No. 11) was 0.60 v.[12] These two latter values are too large because no correction has been made with reference to the dynamics of the vibrating column. The extreme readings would be affected appreciably on this account, but the correction could be ascertained.

Considering the fact that no recording or damping device was introduced, the general consistency of the figures in the table is perhaps more remarkable than is at first apparent. It should be noted that the probable error for a single mean by either method amounts to much less than 1 mile per hour in the calculated velocity. The extreme difference obtained in the unexplained variation of observation No. 11, amounts to 3 mi./hr., and there were only two other cases where the difference amounted to 2 mi./hr. In Table 2 it will be seen that the mean values for the wind during the whole test were in complete agreement for both types of instrument.

These tubes were used very successfully for recording the number of the gusts in a given period, as well as their comparative range and approximate velocity. A summary of some results obtained in this way is given by Mr. J. Patterson, and the present writer in a section of Dr. L. V. King's Report.[13] Checks were made on this method of indicating the frequency of gusts or double fluctuations of pressure (1) by watching the behavior of a small tethered pilot balloon, (2) by comparing with the record of a Dines's microbarograph, and (3) by counting the successive dark regions which were caused on the surface of the water on a day when the gustiness was very marked. A fair agreement was obtained.

Section 5. The hot-wire anemometer under open-air conditions.—In his work on the linear hot-wire anemometer, Dr. L. V. King describes a satisfactory portable form [14] with which precision measurements of both regular and turbulent flow can be performed to a much higher order of accuracy than can be obtained with any of the ordinary instruments. This outfit was brought down to Father Point and it had been hoped to test it thoroughly under open-air conditions with reference to its possible use in the study of gustiness and other problems of atmospheric structure. Unfortunately, owing to the press of the main investigation, there was not time even to complete a series of comparisons with the other anemometers. A preliminary test was, however, carried out; and it was sufficiently suggestive to justify these references here, and lead to the opinion that a method so promising should at once be recommended strongly for further development and application.

The fragility of the wires, the danger of their "burning out," and the extreme sensitiveness, were the only apparent disadvantages of the instrument for open-air work, and these were apparent because the apparatus had been taken outside just as it was, although designed for special laboratory tests. It is evident that disadvantages of this type should not present insuperable difficulties. The advantages that were immediately noted were striking. For sensitiveness and resolving power in indicating fluctuations, and for general range (provided that allowance was made for the influence of the atmospheric temperature on the constants of the instrument) it far surpassed the other instruments, while in regard to accuracy and freedom from error there does not seem to be any reason why precision results may not be obtained of the same order as those found generally in electrical measurements. In the field of aeronautical engineering the method should prove to be a most valuable aid.

The calibration curve for these instruments is of the form

$$V = A^2 (i^2 - B)^2$$

where V is the velocity of the flow, i is the electric current, and A and B are constants which can be determined [15] with accuracy, either directly from theory or by experimental calibration. In the case of the particular wire used at Father Point (No. 23 of Dr. King's calibrated set) the formula was

$$V = 3.24\ (i^2 - 0.715)^2$$

where V is the velocity in mi./hr. and i is the electric current measured in amperes.

The figures in Table 4 illustrate the type of observation obtainable. These readings were taken in 14 minutes as shown and were recorded each time the ammeter needle assumed temporarily a new mean position.

TABLE 4.—*Observations in the open air with the hot-wire anemometer.*

Time.	Ammeter reading. (i)	Calculated wind velocity. $V = 3.24(i^2 - 0.715)^2$	Robinson cup averages. (V)
	Amperes.	*Mi./hr.*	
3.31 p. m.	1.51	7.9	The average velocity for half-minute periods varied from 3 mi./hr. up to 7 mi./hr.
	1.47	6.8	
	1.46	6.5	
	1.45	6.2	
3.37 p. m.	1.41	5.3	
	1.34	3.7	
3.38 p. m.	1.34	3.7	
	1.35	4.0	
3.42 p. m.	1.33	3.6	
	1.30	3.1	
3.44 p. m.	1.46	6.5	
Mean		5.2	5 mi./hr.

There was no object in making a closer comparison with the Robinson cup, since the hot-wire readings were mean values for short intervals of time while the Robinson cup readings were obtained only as averages for half-minute periods. A comparison of *self-recording* instruments of this type with others must be performed before a complete estimation of the value of the open-air use of this anemometer can be made.

Some simple tests of sensitiveness were made by blowing and fanning at various distances from the hot wire, and the claims of its designer in this respect appear to be justifiable. A further test made in comparison with the kata-thermometer is mentioned in the next section.

[12] Compare these four values with the results (1. 2 v, 0.75 v, 1. 3 v, and 0.65 v, respectively) given by W. N. Shaw, in Report of the Adv. Com. for Aeronautics (Brit.), 1909–10, p. 97; also G. C. Simpson in M. O. Pub. 180, p. 37.

[13] Loc. cit.

[14] L. V. King, loc. cit., see p. 9 for photograph of outfit. Also see L. V. King, "On the convection of heat from small cylinders in a stream of fluid: Determination of the convection constants of small platinum wires with application to hot-wire anemometry," Phil. Trans. Roy. Soc. Lon. A vol. 214, p. 404 (1914), where a full treatment is given, and plates shown in illustration of the apparatus.

[15] As shown by L. V. King, loc. cit.

Section 6. The kata thermometer used as an anemometer.—The theory of the dry-bulb kata thermometer considered as an anemometer, is similar to that of the hot wire; in each case the velocity is obtained from observations depending on the rate of cooling of a hot cylinder. In the kata thermometer, however, the difference in temperature between 36.5° C., the average temperature of the bulb, and the surrounding air is such that the constant of the instrument varies appreciably with it and readings can be considered accurate only for low velocities; while in the case of the hot wire the difference is so large that for many ordinary purposes the constant may be taken as independent of the surrounding temperature, although the correction can be readily calculated when wanted.

The formula, $V=A(i^2-B)^2$ given above for the hot wire becomes, since H varies as i^2,

$$V=a(H-b)^2$$

where V is the velocity as before, H is the heat lost in millicalories per square centimeter per sec., and a and b are the constants for the instrument and the particular units chosen. The constants are really functions of θ, where $\theta=(36.5-t)$°C. and t°C. is the surrounding temperature. It can be shown that $a=c/\theta^2$ and $b=d\theta$, where c and d are the remaining constants, and therefore, that,

$$V=c\left(\frac{H}{\theta}-d\right)^2$$

A full treatment of the theory of the instrument and its use is given by its designers,[16] and for the type used at Father Point, they give the equation $H/\theta=0.27+0.36V^{1/2}$ where V is in met./sec., which in the above form with V in mi./hr., becomes

$$V=17.2\left(\frac{H}{\theta}-0.27\right)^2$$

In Table 5 a number of observations are shown which illustrate the readings obtainable under open air conditions. The value H was obtained in the usual way by observing the time of cooling in seconds from 100° F. to 95° F. with a stop watch, and dividing this into the kata factor, which was 522 for our apparatus. The bulb was heated conveniently before observation by means of hot water carried in a thermos bottle. It was important to screen the bulb from direct radiations.

TABLE 5.—*Observations with the dry-bulb kata thermometer used as an anemometer under open-air conditions.*

Time of cooling.	Rate of heat loss.	Temperature difference.	Calculated velocity.	Robinson cup values (average for whole minute intervals).	Place of observation.
(ϕ.)	($H=522/\phi$.)	$\theta=(36.5-t)$° C.	$V=17.2(H/\theta-0.27)^2$.	(V.)	
Seconds.	*mc./sec.*	°	*mi./hr.*	*mi./hr.*	
19.6	26.6	31.8	5.5	6	Near Robinson cup No. 2 at elevation of 6 feet.
18.8	27.8	31.8	6.3	6	Do.
23.8	21.9	31.8	3.1	3	Do.
20.8	25.1	25.9	8.4	10	Top of 40-foot met. tower.
19.2	27.2	25.9	10.5	10	Do.
14.0	37.4	29.7	16.9	([17])	Top of 80-foot lighthouse.
17.8	29.3	22.1	19.0	20	Near ground.

[16] Hill, Griffith, and Flack, loc. cit.
[17] 13 mi./hr. on 40-foot tower, ½ mile away.

As these Robinson cup readings are averaged over 1 minute intervals, while the kata readings are averages over the number of seconds shown, no closer agreement could be expected. The results are sufficient to demonstrate the apparent value of the instrument for obtaining the average wind velocity during the time of observation. A constant-temperature, electrically-heated bulb of this kind, arranged to self-record would probably be a valuable asset in many practical problems of anemometry.

The kata was also compared directly with the hot wire. In Table 6, the first column gives the value of V calculated as in Table 5, from the kata thermometer, and the second column gives the various values of V during the period of the kata observation which were obtained with the hot-wire instrument as in Table 4. The third column gives the mean value of the groups in the second column.

TABLE 6.—*Comparison of kata thermometer and hot-wire anemometer under open-air conditions.*

	The velocity as determined by the kata thermometer.	The velocity as determined by the hot-wire anemometer.	Mean velocity for hot-wire anemometer.
	Mi./hr.	*Mi./hr.*	*Mi./hr.*
1	6.3	6.7 6.5 6.2	6.5
2	3.3	3.7	3.7
3	3.1	3.6 3.1 3.2	3.3
4	[1] 11.1	11.5 11.2 11.9	[1] 11.5

[1] The readings in this case were not simultaneous.

The wet-bulb kata thermometer was also tried as an anemometer, but in the few tests made, was found to be much less satisfactory in open-air conditions. This is no doubt due to the extra evaporation factor, and there were indications that a correction might be needed in the formula which was used.[18]

It is desirable that the matter should be examined further before the observations can be satisfactorily interpreted. It is of some importance because if the formula had to be modified it would affect, also, the ordinary interpretation of the "comfort factor" in cases of strong wind or extreme drafts.*

Sec. 7. Additional remarks and summary.—A small turbine vane which had previously been calibrated in terms of a standard instrument was also tested in connection with one of the experiments. It gave under open-air conditions, the same results to within 1 mi./hr. as the Robinson cups and the Pitot tube, for averages taken over a minute. Tests were made on velocities up to 10 mis./hr.

In testing any of these instruments it was noticed that in gusty weather, it was essential either that the instruments compared, should be situated very near to each

[18] The formula given by Hill, Griffith, and Flack (loc. cit. p. 212) for the wet kata thermometer was $H=(0.27+0.36V^{1/2})\theta+(0.085+0.56V^{1/2})(F-f)^{4/3}$ where V is in met/sec. H and θ have the same significance as before, F is the max. vapor pressure in mm. at 36.5° C. and f is the existing vapor pressure in mm.

*Interesting discussions of the measurement of bodily comfort appeared in *Nature*, London, 1915, vol. 95: L. Hill, "Healthy atmospheres," pp. 205-207, contains pictures of the kata thermometer and caleometer; J. R. Milne, "Man's true thermal environment," p. 259, discusses Hill's article and describes a "psuchrainometer," an instrument to measure cooling; G. W. Grabiam's discussion of the inapplicability of the psuchrainometer to conditions in the tropics, and Milne's reply are on pp. 451 and 508. In the *Scientific American*, May 8, 1915, p. 431, there is a historical discussion, "Measuring atmospheric comfort." An account of experiments with "The kata thermometer as a measure of the effect of atmospheric conditions upon bodily comfort," was published by C. E. A. Winslow in *Science*, New York, 1916, N. S., vol. 43, pp. 716-719; and a somewhat similar one by A. N. Shaw in Trans. Roy. Soc. Canada, 1917, vol. 11, pp. 121-127.—C. F. B.

other, or that the average should be taken over a time which was at least five times longer than the period between gusts.

It was found throughout that comparisons of this kind were more trustworthy on occasions when the gusts seemed to be traveling as cylindrical eddies with horizontal axes. If the axes were tilted or vertical, the extra fluctuations in direction rendered the readings much more erratic and difficult to interpret. Near prominent topographical features, or buildings, such effects were very marked.

SUMMARY.

1. A comparison between the wind velocities determined with a Robinson cup anemometer at an elevation of 40 feet and those calculated from observations on a pilot balloon drifting past it, showed a very satisfactory agreement between the two methods of observation under open-air conditions.

2. A simple Pitot tube, which could be constructed with ease in any laboratory, was tested under open-air conditions and found to give satisfactory results with the theoretical formula $v^2 = 2P/\rho$.

3. Its use for the detection and measurement of gustiness was demonstrated. It was found that the relation between the mean gust velocity, the mean lull velocity, and the mean velocity could be satisfactorily investigated with a Pitot tube of this type.

4. The linear hot-wire anemometer as developed by Dr. L. V. King was tested under open-air conditions and appeared to be the most promising of anemometers from the standpoint of precision. The claims of its designer seem to be justified.

5. The kata thermometer which was used as an anemometer for various velocities up to 20 mis./hr. was found to give results in accordance with the other instruments.

Very many thanks are due to Dr. L. V. King for making these incidental tests possible while using the instruments for the acoustical investigation. To Mr. J. Patterson the writer is especially thankful for the opportunity to acquire experience and interest in meteorological work, and takes great pleasure in recording his indebtedness. It is also a pleasant duty to thank Lieut. E. Bieler for his kind assistance in taking simultaneous observations.

SOUTHERN CALIFORNIA WINDSTORM OF NOV. 24-26, 1918.

By FORD A. CARPENTER, Meteorologist.

[Dated: Weather Bureau, Los Angeles, Feb. 6, 1919.]

During November, 1918, southern California experienced the heaviest wind for more than two score years. The highest wind ever recorded since the establishment of the weather service in southern California occurred at Mount Wilson during this wind storm, when the anemometer registered 90 miles an hour.

The article by Special Meteorological Observer W. P. Hoge describes the beginning of this three-day wind and its effects, and his accompanying photograph of the anemometer sheets shows the steadiness of the wind. The damage inflicted on the forest of Mount Wilson is well shown by his photograph (fig. 3) and may be duplicated in many portions of the forest reserve. Shortly after this storm my work took me into the mountains and I found many of the trails partially blocked by fallen timber.

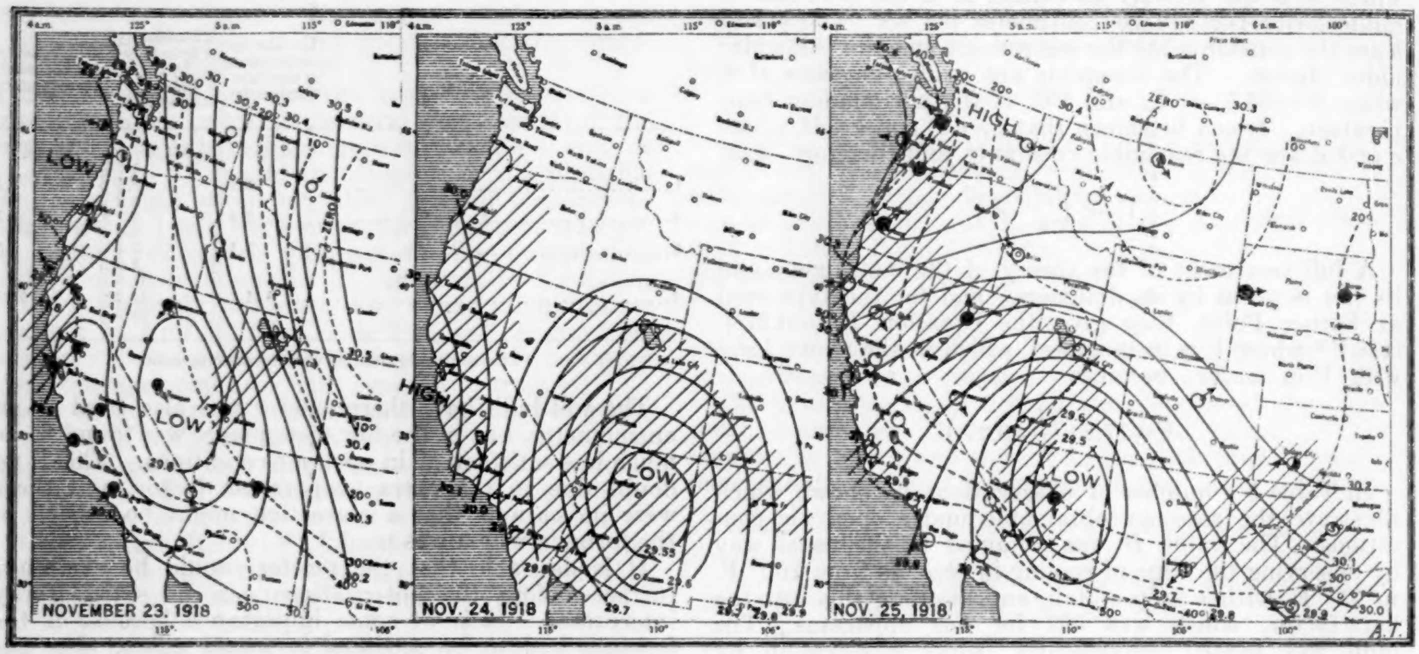


FIG. 1.—Weather maps showing successive positions of the southwestern cyclone, 5 a. m. (120th Mer. time), November 23, 24, and 25, 1918.

The weather map of the morning of November 23 (fig. 1) showed a well-developed low area entering the southwestern Pacific coast. Storm flags were ordered by the district forecaster stating that a moderate to strong westerly gale would occur within the next 12 to 24 hours. The LOW progressed slowly eastward giving northwesterly gales throughout southern California. Like many disturbances of this character, the LOW disintegrated after three days of life; the weather map of the 25th showing the last distinctive formation of the LOW.

In order to show that the wind of November 23 was of unusual strength it is only needful to compare the curve of hourly velocity of that day with the mean hourly curve of the whole month. (See fig. 2.) The mean hourly ve-

FIG. 3.—Anemometer location on top of the dome, Mount Wilson Observatory solar telescope tower, at a height of 175 feet above ground, or 5,900 feet above sea level. (Photographed by F. A. Carpenter.)

locity for 6 a. m. is 13 miles, while 84 miles was recorded at that hour on the 23d. Mountain stations in this vicinity ordinarily record a maximum velocity for the first half of the day at 6 a. m., and for the last half about

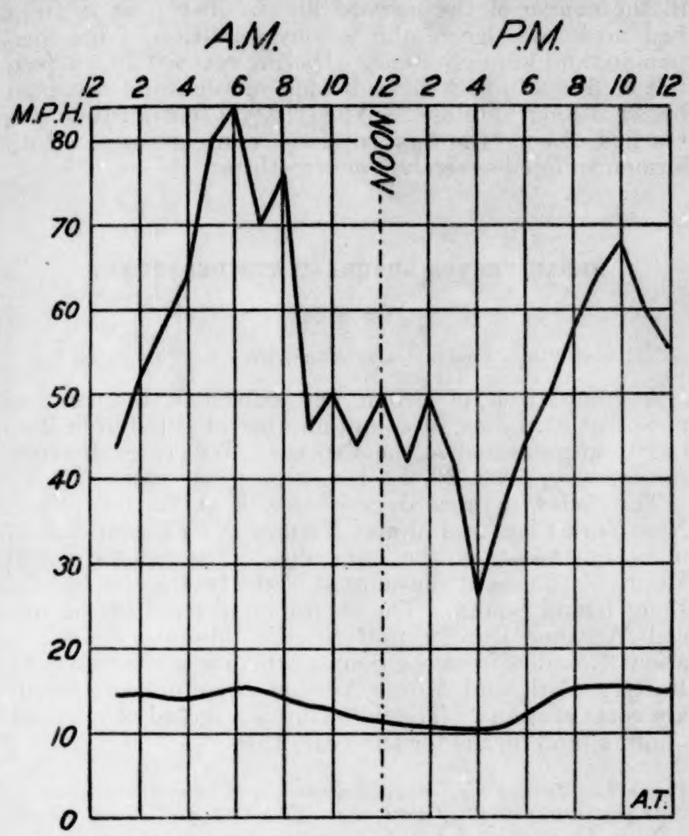


FIG. 2.—Hourly wind velocity on Mount Wilson, Cal., during November, 1918.

10 p. m. At 10 p. m. of the 23d the wind registered 66 miles per hour, or 54 miles above the average for the month at that hour.

The location of the station anemometer on Mount Wilson has been described by Mr. Hoge in his article, but it is thought that the accompanying photograph (fig. 3) may give increased knowledge as to exposure.

The wind was general throughout southern California on the dates noted, as will be seen by perusal of the table showing wind velocities at neighboring stations. The maximum velocity occurred at all five stations on the 24th but with a distinct lag of 15 hours at Los Angeles and San Pedro, and 5 hours at Arcadia and Santa Monica. The relative position of these stations may be found by consulting fig. 4, which is a projection profile showing the relationship of Mount Wilson to the other stations.

TABLE 1.—*Maximum wind velocities during November, 1918.*

Station.	Day.	Maximum velocity in 5 minutes, miles per hour.	Direction of maximum velocity.	Time of maximum velocity. (120th Mer.)	Elevation of anemometer above sea.
					Feet.
Mount Wilson	24	90	NNW.	4.25 a. m.	5,900
	25	60	NNW.	12.25 p. m.	5,900
	26	48	NNW.	1.00 a. m.	5,900
Arcadia balloon school*	24	36	NW.	7.00 a. m.	3,000
	24	80	NW.	10.30 a. m.	11,000
Los Angeles	24	38	NW.	12.20 p. m.	458
	25	29	NW.	12.13 p. m.	458
	26	15	NW.	9.43 p. m.	458
Santa Monica	24	60	NW.	9.00 a. m.	200
	25	50	NW.	9.00 a. m.	200
	26	48	NW.	1.00 a. m.	200
San Pedro	24	45	NW.	11.00 p. m.	112
	25	38	NW.	12.25 p. m.	112
	26	24	SW.	1.00 a. m.	112

* Theodolite observations of pilot balloons.

As to the effect of this windstorm, the greatest damage was to the trees both in the forest and in the cities and towns. Several hundred shade trees were blown down in Los Angeles and Pasadena; and tents were demolished at San Pedro, and shipbuilding was interrupted for a time. The equipment of the balloon school at Arcadia was not injured as upon receipt of the warnings no ascents were made and the balloons were hauled down and securely lashed. No damage resulted on the coast, for the storm-warning displays were generally heeded by the fishermen and masters of other coastwise craft.

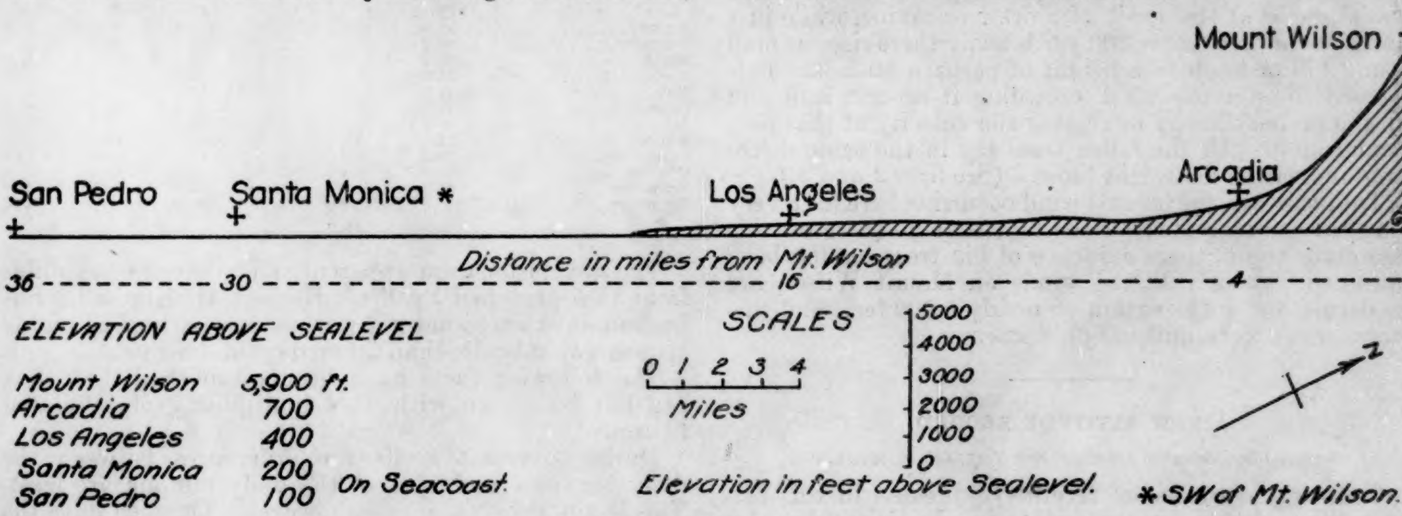


FIG. 4.—Projection profile Mount Wilson to the seacoast.

THE TERRIFIC WINDSTORM ON MOUNT WILSON, CAL., NOV. 24-26, 1918.

By WENDELL P. HOGE.

[Dated: Mount Wilson Solar Observatory, Cal., Dec. 18, 1918.]

A wind storm of unusual velocity and duration occurred at Mount Wilson, Cal., on November 24, 25, and 26, 1918. A rain storm beginning at 2:30 p. m. the 23d, accompanied by a moderate SSW. wind, ended with a heavy shower at 11:30 p. m., giving a total precipitation of 1.02 inches. Immediately after the rain ceased the wind veered to the NNW., increasing in velocity rapidly, registering 40 miles an hour at midnight. Thereafter it increased steadily, reaching a maximum of 90 miles per hour from 4:25 to 4:30 a. m., November 24. From 5 to 6 a. m. the same date 84 miles per hour was recorded, after which there was a slight diminution, but an unusually high velocity was maintained with great constancy for a period of 52 hours, or until nearly 4 a. m., November 26. From 3 a. m. to 8 a. m., the 24th, an average velocity of 75.4 miles was maintained. From midnight the 23d to midnight the 24th there was a wind run of 1,319 miles, being an average of 55 miles per hour. For the 52 hours duration of the high wind the average velocity was nearly 50 miles per hour. (See fig. 1.) The direction was almost constant from about NNW. The anemometer recording these velocities is on the top of the tower telescope building of the Mount Wilson Observatory, being 175 feet above ground, 150 feet above the highest part of the mountain, 75 feet above the tallest tree tops, and 5,900 feet above sea level.

All buildings of the observatory withstood the storm. The only damage was the destruction of six big yellow-pine trees and one Norway spruce, all located in a small area about a hundred yards northeast of the 100-inch telescope dome. The largest pine tree destroyed is 5 feet in diameter and estimated to be no less than 350 to 400 years old. Six of the trees were torn up by roots and one snapped off some 20 feet above the ground. There are many other large trees scattered about the mountain top exposed directly to the north winds but none were blown over except as noted above. This seems to be accounted for by the fact that the group blown down was situated at the head of a draw or ravine, while just north of the trees some 200 yards away there rises a small round hill or knob to a height of perhaps 80 feet. This seemed to split the wind, crowding it around into and up the ravine thereby increasing the velocity at that particular spot. All the fallen trees lay in the same direction, indicating a straight blow. (See figs. 2 and 3.)

That this was the highest wind occurring here for a very long time is indicated by the fact that nowhere on this mountain top is there evidence of big trees having been uprooted. As a rule, the winds on Mount Wilson are moderate, for an elevation of nearly 6,000 feet, and this storm was a very unusual phenomenon.

A NEW ALTITUDE RECORD.

[Reprinted from Scientific American, New York, Feb. 22, 1919, p. 165.]

Contrary to the belief recently expressed in this column, the altitude record of Capt. R. W. Schroeder recently made at Dayton, Ohio, did not endure for very long.* All altitude records were again broken on January 2 last, when Capt. Lang, R. A. F., and Lieut. Blowers, the former acting as pilot, ascended to 30,500 feet in 66 minutes and 15 seconds. A two-seater biplane fitted with a British-designed and British-built engine, was employed in making this new record. Due to the breaking of his oxygen-supply pipe, Lieut. Blowers collapsed in the course of the upward flight. The pilot in front had no knowledge of the serious condition of his companion, and kept climbing. Having reached 30,500 feet, the engine stopped through lack of fuel, and the pilot began a long volplane. When 10,000 feet altitude was reached, Lieut Blowers regained consciousness. Both airmen suffered severely from frostbite.

* Cf. M. W. R., 1918, 46:405.

URBAN VERSUS SUBURBAN TEMPERATURES.

By J. W. REDWAY.

[Dated: Meteorological Laboratory, Mount Vernon, N. Y., Jan. 24, 1918.]

A comparison of urban and suburban temperature means at St. Louis, Mo., and another at Pittsburgh, Pa., has been published in the MONTHLY WEATHER REVIEW for January, 1902, **30**, 12-13.

The following records were made at Battery Park, New York City, and Mount Vernon, N. Y., a suburb 17 miles northeast, as the crow flies. The laboratory at Mount Vernon is at the summit of the first divide beyond Long Island Sound. The thermometers are of the official Weather Bureau pattern; the laboratory itself is about 1.5 miles from the Sound, which is almost in sight. Battery Park and Mount Vernon, therefore, practically are coast stations. The following is a record of maxima, minima, and means for the year, 1918.

TABLE 1.—*Monthly maximum, minimum, and mean temperatures for the year 1918 at Battery Park, New York City, and Mount Vernon, N. Y.*

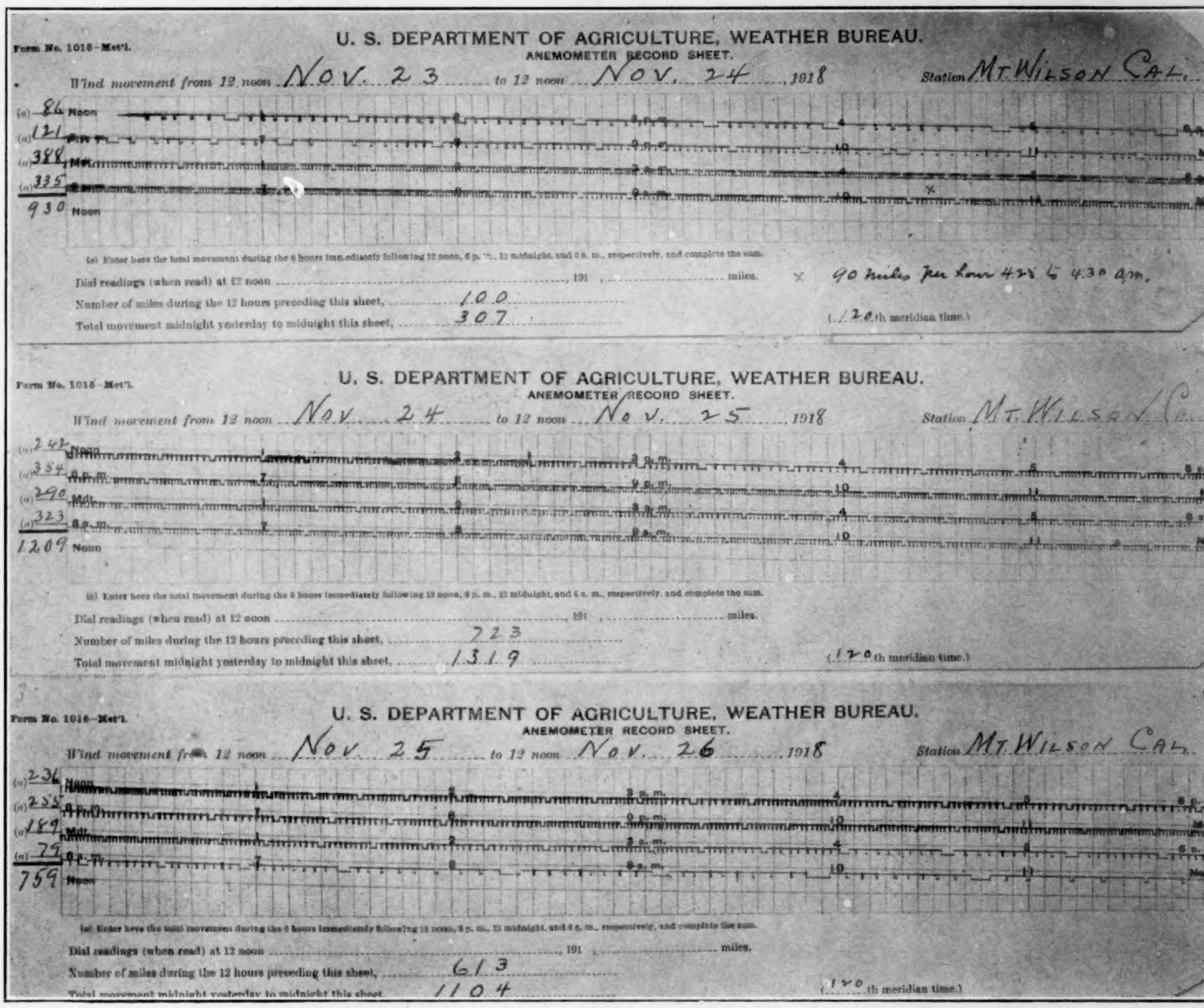
1918.	Maximum temperature.		Minimum temperature.		Mean temperature.	
	Battery Park.	Mount Vernon.	Battery Park.	Mount Vernon.	Battery Park.	Mount Vernon.
	°F.	°F.	°F.	°F.	°F.	°F.
January	28.8	28.5	14.5	13.8	21.6	21.2
February	38.2	38.1	21.1	19.3	29.6	28.7
March	50.7	52.8	31.8	30.1	41.2	41.4
April	58.0	60.6	41.7	39.7	49.8	50.2
May	72.8	73.6	55.0	53.3	63.9	63.5
June	74.0	75.1	58.8	57.3	66.4	66.2
July	80.3	81.6	65.1	63.4	72.7	72.5
August	82.4	83.4	67.3	65.1	74.8	74.2
September	70.2	71.3	55.5	54.0	62.8	62.6
October	66.1	69.1	51.0	48.0	58.6	55.6
November	51.8	55.2	39.6	36.6	45.7	45.9
December	45.5	46.3	32.5	30.0	39.0	38.2

The conclusions are apparent, and they do not differ from those reached by Prof. Herbert H. Kimball. Suburban days are somewhat warmer and surburban nights are somewhat cooler than urban days and nights.

The following facts have been established, but they can not be shown without a multiplicity of tabulated figures.

During overcast spells the differences between the daily maxima and also of the daily minima are least. This is not always the case, however. On such days the difference between maxima has been as great as 5° in favor, not of Mount Vernon, but of Battery Park.

During periods of high winds the minima at the two stations rarely differ. During very still nights the Mount Vernon minima average not far from 3 degrees lower than those of Battery Park.



Form No. 1016—Met'l.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.
ANEMOMETER RECORD SHEET.

Wind movement from 12 noon Nov. 23 to 12 noon Nov. 24 1918 Station Mt. Wilson Cal.

(a) 86 Noon
(a) 121 6 p. m.
(a) 388 Mdt.
(a) 335 6 a. m.
930 Noon

(a) Enter here the total movement during the 6 hours immediately following 12 noon, 6 p. m., 12 midnight, and 6 a. m., respectively, and complete the sum.

Dial readings (when read) at 12 noon ...., 191 ...., ... miles. × 90 miles per hour 4.25 to 4.30 a.m.

Number of miles during the 12 hours preceding this sheet, 100

Total movement midnight yesterday to midnight this sheet, 307 (120th meridian time.)

Form No. 1016—Met'l.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.
ANEMOMETER RECORD SHEET.

Wind movement from 12 noon Nov. 24 to 12 noon Nov. 25 1918 Station Mt. Wilson Ca.

(a) 242 Noon
(a) 384 6 p. m.
(a) 290 Mdt.
(a) 323 6 a. m.
1209 Noon

(a) Enter here the total movement during the 6 hours immediately following 12 noon, 6 p. m., 12 midnight, and 6 a. m., respectively, and complete the sum.

Dial readings (when read) at 12 noon ...., 191 ...., ... miles.

Number of miles during the 12 hours preceding this sheet, 723

Total movement midnight yesterday to midnight this sheet, 1319 (120th meridian time.)

Form No. 1016—Met'l.

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.
ANEMOMETER RECORD SHEET.

Wind movement from 12 noon Nov. 25 to 12 noon Nov. 26 1918 Station Mt. Wilson Cal.

(a) 236 Noon
(a) 255 6 p. m.
(a) 189 Mdt.
(a) 79 6 a. m.
759 Noon

(a) Enter here the total movement during the 6 hours immediately following 12 noon, 6 p. m., 12 midnight, and 6 a. m., respectively, and complete the sum.

Dial readings (when read) at 12 noon ...., 191 ...., ... miles.

Number of miles during the 12 hours preceding this sheet, 613

Total movement midnight yesterday to midnight this sheet, 1104 (120th meridian time.)

FIG. 1.—Anemometer record.

FIG. 2.—Trees uprooted by the gale.

FIG. 3.—Large tree uprooted by the gale.

The higher the moisture content of the air the less the daily differences and vice versa. This is generally, but not always, true.

I feel pretty certain that the dust content of the air affects the daily differences, but I am not yet able to establish the fact. Prof. Kimball has expressed the opinion that the blanket of moisture, smoke, and dust over a city tends to prevent radiation of heat at night, and during the day arrests much of the heat which reaches the suburban station. I see no reason to question this conclusion.

EVAPORATION IN THE CANAL ZONE.

By H. G. CORNTHWAITE, Chief Hydrographer.

[Dated: Balboa Heights, C. Z., Jan. 16, 1919.]

Evaporation is the process by which aqueous vapor is taken up from water surfaces and moist land areas and returned to the atmosphere. The water vapor in the air is derived primarily from the large ocean areas. It is carried about and distributed over the earth's surface by the prevailing winds. Condensation and precipitation complete the "meteorological cycle" and return the water to the earth's surface again in the form of rain or snow.

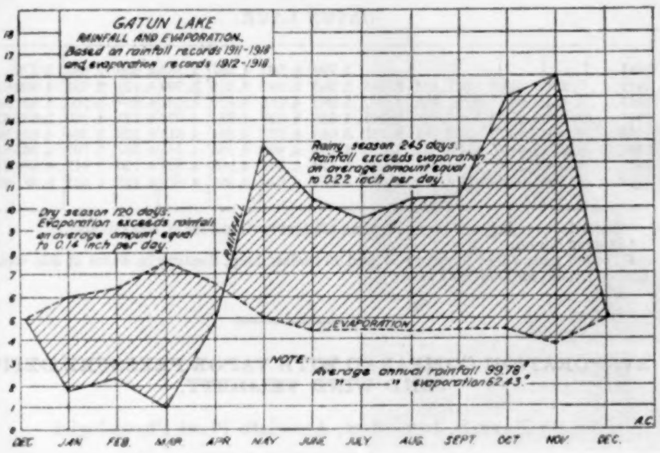


FIG. 1.—Gatun Lake rainfall and evaporation.

The laws of evaporation are complex and not thoroughly understood, but the principal factors controlling the rate of evaporation are wind movement, temperature, and vapor pressure. In regions such as the Canal Zone, where equable temperature conditions prevail, wind movement and vapor pressure are of paramount importance in controlling the rate of evaporation.

Since an adequate water supply is essential to the successful operation of the lock type of canal at Panama, the rate of evaporation from the surface of Gatun Lake has an important bearing on the successful operation of the canal, especially during the four dry-season months when the rainfall and run-off are deficient. In recent years valuable evaporation data have been collected at stations located at Bas Obispo, Rio Grande, and Brazos Brook reservoirs, and on Gatun Lake. These records are discussed herein.

Instrumental equipment.—The equipment at each evaporation station consists of a copper pan 4 feet in diameter and 10 inches deep. floating in the lake. An anemometer for recording the wind movement, a thermometer for registering the water temperature, and a rain gage for measuring the precipitation, complete the instrumental equipment of the station. The evaporation pan is protected from wave action by a wooden frame properly buoyed. In locating evaporation stations the aim has been to obtain conditions within and surrounding the pans as closely as possible approximating the conditions that prevail over the lake surface. The water level within the pans is maintained at approximately 4 inches below the top to prevent the overflow of the pan during heavy rains. A sharp-pointed copper index or zero point is set in the center of the pan. This index is protected by a 6-inch perforated copper cylinder still well, which serves to reduce the wave motion of the water surrounding the index, thus permitting more accurate readings of the daily evaporation.

Readings are made daily by measuring the quantity of water poured into the pan to bring the water surface exactly to the top of the copper index or zero point, due allowance being made for any rainfall that may have occurred since the previous reading. A measuring cup having exactly one one-hundredths the cross-section area of the evaporation pan is used in measuring the quantity of water poured into or removed from the pan.

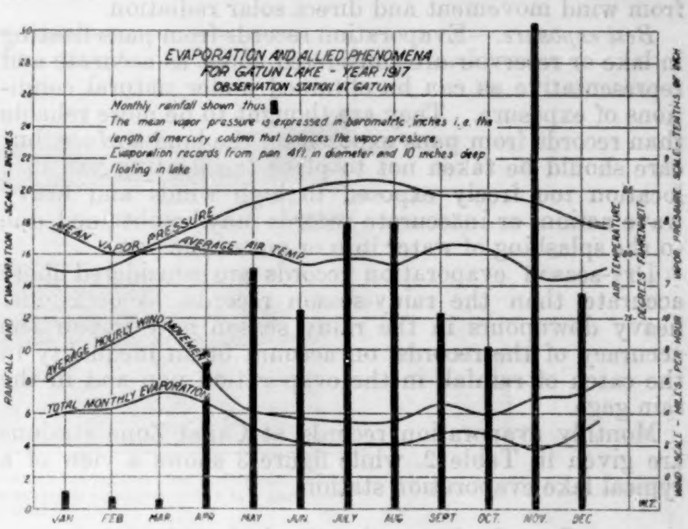


FIG. 2.—Gatun Lake evaporation and allied phenomena for the year 1917.

Evaporation records.—The average annual evaporation from a pan floating on the surface of Gatun Lake is approximately 62 inches. The rate of evaporation is much higher during the dry season than in the rainy season as the dry-season weather conditions favor a higher rate of evaporation. The higher wind movement, low humidity and vapor pressure, light cloudiness and higher day temperatures of the dry season all tend to accelerate the rate of evaporation.

The quantity of water lost from the surface of Gatun Lake during the four dry-season months is nearly as great as the quantity lost during the eight months of the rainy season. The greatest daily evaporation loss of record from Gatun Lake is 0.4 inch, occurring in March, 1918. Fig. 1 shows the relation between the rainfall and evaporation on the surface of Gatun Lake, while fig. 2 shows the relation between evaporation and its allied phenomena on the lake for the year 1917. The close parallelism of the monthly evaporation and the average wind velocity curves is noticeable; also the inverse relationship of the rainfall and evaporation curves.

Day- and night-time evaporation.—Comparative records of the day and night evaporation indicate that approxi-

mately 60 per cent of the evaporation loss occurs during the daytime, 8 a. m. to 8 p. m., and 40 per cent at night. Comparative day and night evaporation records are given in Table 1.

Variations in rate of evaporation.—Evaporation records were obtained from selected locations on Gatun Lake, to determine the relative rates of evaporation from the open sections of the lake and along the grass and timber covered margins. One floating pan was anchored well out in the open section of the lake. Another was located in the timber fringe bordering the south shore and a third was placed in the midst of a grassy marsh. The records were continued for six months during the rainy season, with the following results:

Evaporation from open lake, 100 per cent.
Evaporation from timber fringe, 72 per cent.
Evaporation from grassy marsh, 75 per cent.

The higher rate of evaporation from the open sections of the lake is due, principally, to the greater wind movement there, which tends to prevent the accumulation of a vapor blanket directly overlying the water surface. The rate of evaporation from the protected margin of the lake varies, depending upon the degree of protection from wind movement and direct solar radiation.

Best exposure.—Evaporation records from pans floating in lake or reservoir are considered about as accurate and representative as can be obtained under natural conditions of exposure. They are thought to be more reliable than records from pans exposed on the land surface, but care should be taken not to place the floating pan in a location too freely exposed to high winds and heavy wave action, or inaccurate records may be obtained, due to the splashing of water into or out of the pan.

Dry-season evaporation records are considered more accurate than the rainy-season records, as occasional heavy downpours in the rainy season may impair the accuracy of the records, on account of an inequality in the catch of rainfall in the evaporation pan and in the rain gage.

Monthly evaporation records at Canal Zone stations are given in Table 2, while figure 3 shows a view of a typical lake evaporation station.

TABLE 1.—*Comparative values for day and night.*[1]

Month.	1908[2]						1909			
	Ancon.		Bas Obispo.		Cristobal.		Ancon.		Cristobal.	
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.
	Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
January	......	......	......	......	......	......	1.755	1.593	2.754	2.114
February	5.062	1.495	3.605	2.124	4.200	3.758	2.134	1.594	2.916	2.437
March	5.566	1.431	3.919	2.371	4.402	3.155	2.693	2.238	3.660	2.785
April	4.404	1.517	3.630	1.845	3.999	2.931	2.108	1.775	3.594	2.873
May	2.001	1.218	1.715	1.460	1.706	0.864	1.317	1.134	2.268	1.600
June	2.034	1.012	1.955	1.460	1.878	1.306	0.941	0.975	1.332	1.166
July	1.900	1.117	1.670	1.580	1.584	1.238	1.078	1.002	1.252	1.193
August	2.175	1.028	1.702	1.723	1.985	1.207	1.241	1.030	1.467	1.169
September	1.924	1.125	2.178	1.457	2.096	1.231	1.425	1.059	1.706	1.021
October	2.051	1.205	2.467	1.408	2.016	1.308	1.862	0.964	1.784	1.243
November	1.362	1.052	1.555	1.175	1.572	1.128	1.395	0.937	1.129	0.821
December	1.337	1.605	2.040	1.405	2.252	1.804	1.775	1.245	1.484	1.262
Total	29.816	13.805	26.436	18.008	27.690	19.930	19.724	15.546	25.346	19.684
Per cent	68	32	60	40	58	42	56	44	56	44

[1] Readings taken at 8 a. m. and 8 p. m. daily.
[2] 11 months, 1908.
Exposed concrete tank 12½ feet in diameter at Bas Obispo. Protected tanks 10 inches in diameter at Ancon and Cristobal.

TABLE 2.—*Monthly evaporation records.*[1]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
BAS OBISPO.													
	Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
1907	5.175	5.072	6.538	6.486	4.681	3.125	3.152	3.582	3.358	2.938	3.599	4.896	52.602
1908	5.617	5.729	6.290	5.475	3.175	3.415	3.250	3.425	3.635	3.875	2.730	3.445	50.061
RIO GRANDE.													
1909	.....	.....	.....	5.960	4.205	3.417	3.117	3.353	3.768	3.094	2.713	2.993	......
1910	4.612	5.529	6.003	3.986	3.916	2.654	2.846	3.096	3.677	3.577	2.999	3.442	46.337
1911	5.940	4.912	7.462	5.139	4.015	3.646	4.989	4.564	4.096	3.924	3.055	5.344	57.086
1912	6.363	6.134	7.099	6.732	5.350	3.836	3.908	3.983	3.335	3.763	3.275	4.723	58.501
1913	5.392	5.544	6.762	6.436	4.033	3.812	3.963	3.901	3.783	3.758	2.741	4.525	54.950
1914	5.520	5.965	7.062	6.413	4.870	3.733	5.084	4.520	([2])	([2])	([2])	([2])	([2])
BRAZOS BROOK.													
1909	.....	.....	.....	5.366	4.597	3.806	3.042	3.760	4.169	4.168	2.152	2.379	......
1910	4.622	4.668	6.151	5.025	4.304	3.516	3.014	3.189	3.804	4.177	2.718	2.746	47.934
1911	6.293	5.115	6.872	4.939	3.290	2.917	4.358	4.066	4.101	3.937	3.364	5.176	54.428
1912	6.066	5.572	7.081	7.321	5.707	3.729	4.425	4.611	4.487	3.970	3.100	4.860	60.929
1913	6.387	6.616	8.455	7.466	4.167	4.500	4.277	4.248	4.934	4.343	3.071	4.747	63.211
1914	6.331	6.456	7.769	([2])	([2])	([2])	([2])	([2])	([2])	([2])	([2])	([2])	([2])
GATUN LAKE.													
1911	.....	.....	.....	.....	.....	2.799	4.560	4.407	4.583	3.609	2.681	3.376	......
1912	7.208	6.048	7.649	7.394	5.335	3.263	3.889	4.316	3.799	4.123	3.351	4.809	61.184
1913	5.435	6.889	8.602	7.333	4.606	5.083	4.664	4.570	4.934	4.844	3.560	1.291	64.811
1914	4.821	6.298	7.504	6.688	5.262	4.558	5.520	4.684	4.074	4.233	4.180	5.083	62.905
1915	6.398	5.430	6.698	5.781	5.361	5.040	4.107	4.354	4.315	4.228	3.564	4.656	59.932
1916	6.280	5.985	6.424	6.391	5.290	4.430	4.491	4.793	4.545	4.267	3.797	4.865	61.558
1917	6.194	6.229	7.246	6.514	4.903	4.110	3.903	4.008	4.851	4.750	3.617	4.899	61.224
1918	5.548	7.231	8.475	6.502	4.901	4.859	4.690	3.991	4.577	4.127	4.621	5.881	65.403

[1] Records from exposed concrete tank 12½ feet in diameter at Bas Obispo.
[2] Station closed.
Exposed pans 4 feet in diameter and 10 inches deep, floating in water at Rio Grande, Brazos Brook, and Gatun Lake.

EVAPORATION COMPARED WITH VAPOR PRESSURE DEFICIT AND WIND VELOCITY.

By EARL S. JOHNSTON, Associate Plant Physiologist.

[Dated: Maryland Agricultural Experiment Station, College Park, Md., Jan. 31, 1919.]

Atmospheric moisture plays an important rôle in the growth and behavior of plants and can not be overlooked in physiological and ecological studies. Atmospheric moisture conditions have frequently been studied by means of atmometers and the rate at which these instruments lose water has been taken as a measure of the evaporating power of the air.[1] The rate of evaporation from these instruments as well as the rate of transpiration from plants is greatly influenced by wind, by the temperature of the surface as dependent on radiant energy and air temperature, and by the amount of water vapor present in the atmosphere. Many attempts have been made to show a relationship between these conditions and the amount of evaporation, but most of the equations formulated are of little value in field

[1] Objections have frequently been made to the expression "evaporating power of the air." Strictly speaking, the air by its presence hinders the rate of evaporation. The term here used is defined by Dr. B. E. Livingston. "Atmospheric evaporating power refers to the external surroundings of the evaporating surface (usually to the air space above it, about it, etc.) and it need not specially refer to the air itself, for if there were no air present this space would still possess an evaporating power. The evaporating power of the air over a surface is considered as proportional to the reciprocal of the tendency of all the conditions effective in the space over that surface to resist the vaporization of water therefrom." Atmometric units. Johns Hopkins Univ. Cir., March, 1917, p. 160-170. (See especially p. 161.) Other expressions such as "potential evaporation" and "evaporativity" have been suggested.

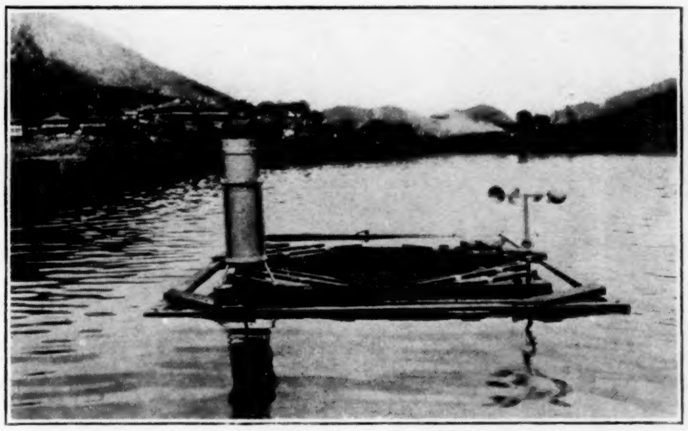


FIG. 3.—Evaporation station, Miraflores Lake. Copper pan 4 feet in diameter and 10 inches deep floating in the lake. The station is equipped with a rain gage, and an anemometer (seen at the edge of the pan).

experiments where only a few simple instruments are used. Atmometer readings can not be used directly when it is desired to study the moisture conditions influencing evaporation independent of air circulation. Recently Livingston [2] has suggested that for a study of such conditions the "index of atmospheric evaporating power" should be equal to the product of the index of the moisture condition and the index of circulation: $I_e = I_m \times I_c$. By moisture condition is meant "that factor in atmospheric evaporating power that is independent of the rate of air circulation." Such a condition includes the air temperature and state of saturation of the space immediately surrounding the evaporating surface. It is further assumed that actual measurements have been properly weighted before applying them as indices. A series of experiments was carried out to determine the approximate accuracy of this equation. The moisture condition measured by atmometers was compared with that calculated from the vapor pressure deficit and wind-velocity measurements.

Measurements of wind velocity and of evaporation from standardized white spherical porous-cup atmometers were made hourly on days representing various combinations of wind and moisture conditions. Vapor pressure deficits were calculated from readings of a hygrometer and thermometer for these same hour periods. These calculations were made by first determining the dew-point for each reading from data given in psychrometric tables [3] and then subtracting the vapor pressure given for the dew-point from the maximum vapor pressure of the air at the given temperature. The vapor-pressure deficit calculated for any hour period was the average of the vapor pressure deficits derived from the readings taken at the beginning and ending of the periods. Attention is called to the fact that the average vapor pressure deficit should not be calculated from the average percentage of relative humidity and the average temperature, since relative humidity and temperature do not always vary in a similar manner. The atmometer and anemometer were freely exposed to the air while the hygrometer and thermometer were exposed within an instrument shelter similar to those employed by the United States Weather Bureau. Data from these instruments and the calculated values are presented in Table I.

Each experiment in Table I is designated by a date of the year 1918. The beginning and ending of each hour period is given as clock time in the first column. In the succeeding columns are given air temperature in degrees Fahrenheit, percentage of relative humidity, vapor pressure deficit in inches of mercury, wind velocity in miles per hour, product of vapor pressure deficit and wind velocity, evaporation in cubic centimeters of water lost from an atmometer corrected to the standard sphere and radiation expressed as the difference in the amounts of water lost from the black and white components of a radio-atmometer.[4] The character of the sky during each period is given in the last column.

[2] Livingston, B. E., The vapor pressure deficit as an index of the moisture condition of the air. Johns Hopkins Univ. Cir., March, 1917. p. 170-175.

[3] Marvin, C. F., Psychrometric tables for obtaining the vapor pressure, relative humidity, and temperature of the dew-point. U. S. Dept. Agric. Weather Bureau No. 235. 1910.

[4] Livingston, B. E., Atmometry and the porous cup atmometer. IV. The radio atmometer. Plant World 18:143-149. 1915.

TABLE I.—*Calculated and observed data.*

Date and period.	Air temperature.	Humidity.	Vapor pressure deficit.	Wind velocity.	Product of vapor pressure deficit and wind velocity.	Evaporation.	Radiation (B-W).	Character of sky.
Sept. 12:	°F.	*Per ct.*	*In. Hg.*	*Mi. hr.*		*Cc.*	*Cc.*	
11-12	74	64	0.308	9.7	2.99	2.6	0.0	Partly cloudy.
12-1	76	54	0.423	8.3	3.51	3.0	1.8	Partly cloudy.
1-2	77	52	0.468	7.2	3.37	3.0	1.1	Partly cloudy.
2-3	78	51	0.484	6.2	3.00	3.1	0.5	Partly cloudy.
3-4	77	53	0.451	6.9	3.11	2.5	0.9	Cloudy.
4-5	76	58	0.388	8.3	3.22	2.2	0.9	Cloudy.
Aug. 16:								
7-8	66	76	0.162	1.6	0.26	0.5	0.7	Clear.
8-9	73	66	0.288	3.6	1.04	0.7	2.0	Clear.
9-10	78	48	0.491	3.5	1.72	2.9	1.3	Clear.
10-11	80	37	0.643	5.5	3.54	3.7	1.4	Clear.
11-12	82	34	0.712	5.9	4.20	4.1	1.7	Clear.
12-1	83	33	0.740	5.1	3.77	4.7	1.8	Slightly cloudy.
1-2	84	32	0.765	5.0	3.82	4.3	1.8	Slightly cloudy.
2-3	84	32	0.765	6.1	4.67	4.9	1.3	Partly cloudy.
3-4	84	32	0.765	4.7	3.60	4.1	1.8	Partly cloudy.
4-5	84	33	0.776	4.1	3.18	3.5	2.2	Partly cloudy.
5-6	84	35	0.736	4.5	3.31	4.0	0.7	Slightly cloudy.
Aug. 20:								
10-11	72	51	0.397	2.6	1.03	2.3	1.5	Slightly hazy.
11-12	74	46	0.451	5.4	2.44	3.2	1.9	Slightly hazy.
12-1	75	42	0.514	7.1	3.65	3.8	1.8	Slightly hazy.
1-2	77	38	0.571	6.1	3.48	4.0	1.6	Slightly hazy.
2-3	78	35	0.625	6.2	3.87	4.1	2.1	Slightly hazy.
3-4	78	34	0.632	6.6	4.17	4.6	1.1	Slightly hazy.
4-5	77	36	0.598	5.0	2.99	3.5	1.5	Slightly hazy.
Sept. 21:								
10-11	56	52	0.217	13.4	2.91	2.4	0.8	Partly cloudy.
11-12	57	49	0.237	13.9	3.29	2.7	0.5	Cloudy.
12-1	58	47	0.254	13.8	3.51	3.1	1.1	Cloudy.
1-2	59	47	0.263	14.3	3.76	3.7	0.7	Cloudy.
2-3	60	46	0.271	10.2	2.76	3.0	0.5	Partly cloudy.
3-4	60	44	0.293	8.7	2.55	2.0	1.1	Partly cloudy.
4-5	60	46	0.288	9.9	2.85	2.9	0.1	Partly cloudy.
Aug. 23:								
9-10	77	65	0.333	5.1	1.70	2.2	1.0	Clear.
10-11	81	58	0.453	5.4	2.45	2.5	1.5	Clear.
11-12	84	53	0.559	6.8	3.80	3.0	1.6	Clear.
12-1	86	48	0.646	9.4	6.07	4.8	2.0	Clear.
1-2	87	45	0.707	7.3	5.16	4.5	1.6	Clear.
2-3	89	44	0.780	7.8	6.08	4.7	1.5	Clear.
3-4	89	43	0.800	7.8	6.24	4.6	1.5	Slightly cloudy.
4-5	88	42	0.777	7.6	5.90	4.6	1.5	Slightly cloudy.
Sept. 28:								
9-10	53	83	0.069	1.5	0.10	0.5	0.4	Slightly hazy.
10-11	58	71	0.145	2.3	0.33	0.6	0.6	Slightly foggy.
11-12	62	58	0.240	4.6	1.10	2.0	0.2	Slightly hazy.
12-1	65	49	0 314	9.2	2.89	2.2	1.5	Slightly hazy.
1-2	67	44	0.374	10.2	3.82	3.4	1.2	Cloudy.
2-3	68	43	0.409	9.3	3.80	3.2	0.7	Cloudy.
3-4	68	42	0.414	9.9	4.10	3.1	0.8	Slightly cloudy.
4-5	68	42	0.396	8.7	3.45	3.5	0.7	Slightly cloudy.

These data, plotted as ordinates, are represented in figures 1 and 2. Each value is plotted at the end of its respective period along the abscissas. In figure 1 the vapor pressure deficit values are represented as dotted lines, wind velocity as dash lines, and evaporation as *light* full lines. The *heavy* full lines represent the product of vapor pressure deficit and wind velocity values. In figure 2 the graphs of evaporation are repeated in order to facilitate comparison with air temperature (dotted lines), relative humidity (dash lines), and radiation (dash-dot lines).

Inspection of figure 1 shows a very good agreement between the calculated evaporation (product of vapor pressure deficit and wind velocity) and that obtained from the atmometers. The effect of sudden changes in wind velocity are registered in several cases. Air temperatures were employed in calculating the vapor pressure deficits. The temperature at the evaporating surface of the atmometer is usually lower than that of the air, thus reducing the actual vapor pressure of the water particles escaping from the atmometer. This vapor is also lowered because the

water evaporates from an imbibing substance and not from a free water surface. From a consideration of these facts it is to be expected that in many cases the actual evaporation values will be somewhat lower than the calculated ones. In bright sunlight, however, when absorbed radiant energy increases the temperature at the evaporating surface, thus increasing the vapor pressure, the actual evaporation values will become more nearly equal to and perhaps exceed those of the calculated. These facts, in part, account for some of the variations in agreement between the graphs of evaporation from this type of atmometer and the graphs of the calculated evaporation.

The average evaporation found in this series of experiments is 3.16 cc. per hour while that of the calculated is 3.24 cc. The approximate accuracy of this simple relation makes it possible to roughly calculate wind velocity from atmometer, hygrometer, and temperature readings, or, to calculate the moisture condition of the atmosphere independent of wind velocity when atmometric and anemometric measurements are available. It is to be remembered, however, that these relations have been tested for a limited range of conditions only and whether such relations will hold true for more extreme conditions has not yet been worked out. In figure 2 the graphs of relative

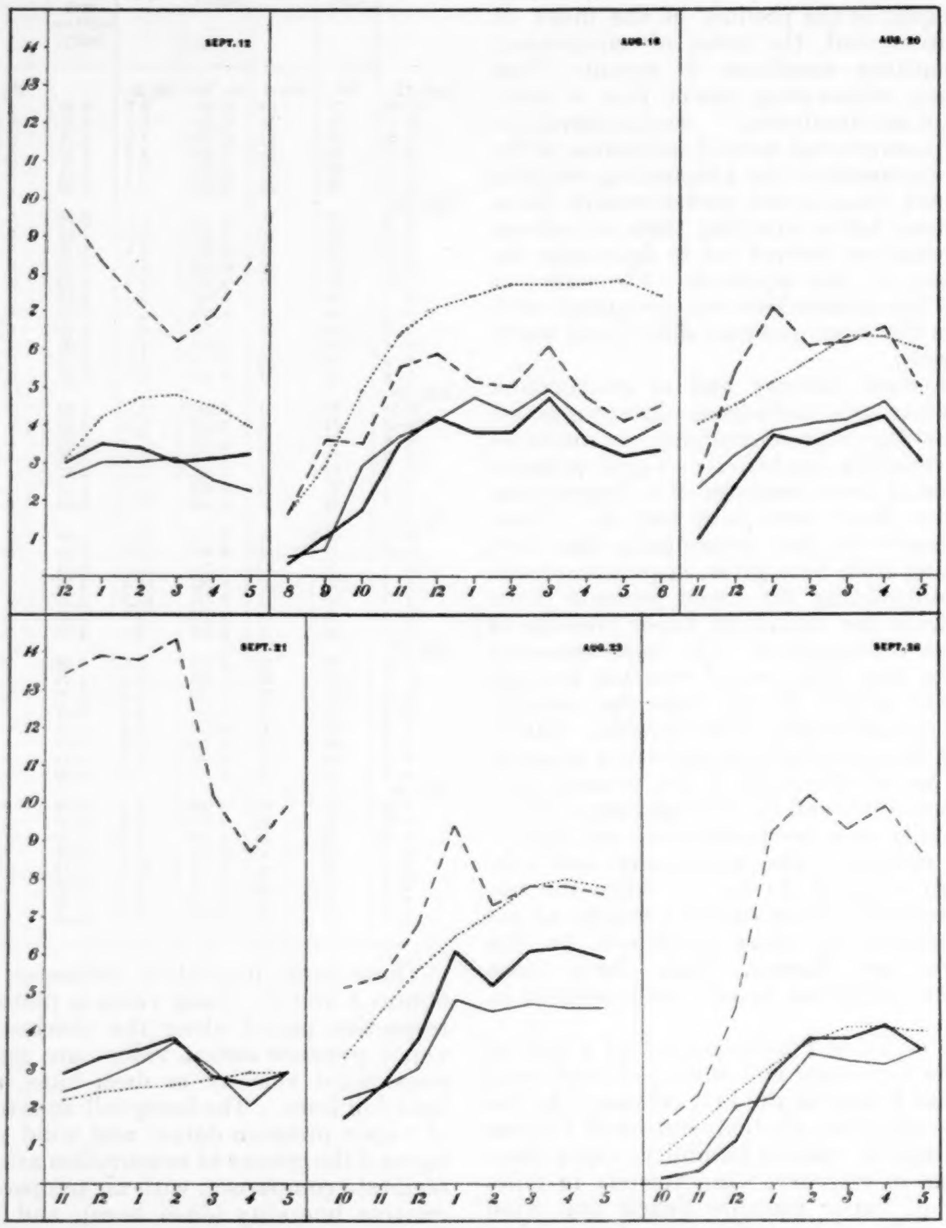


FIG. 1.—Graphs of values representing evaporation from porous-cup atmometers (light full lines), calculated evaporation (heavy full lines), vapor pressure deficit (dotted lines), and wind velocity (dash lines).

humidity and of evaporation deserve special note. The lack of relationship between the graphs of these two kinds of data is clearly seen and the employment of relative humidity independent of temperature is obviously of little importance in evaporation and transpiration studies.

No attempt will be made at this time to show just why or how this approximate relation holds true or to discuss any evaporation formulas. The present purpose is to present the results of a number of experiments that were carried out with the object of testing this particular relation suggested by Livingston. This paper is mainly intended for the ecologist. A suggestion is given as to how relative humidity and temperature data, together with those of wind velocity, may be used apparently to as good advantage as evaporation data. This should help make a large amount of the valuable data collected by the Weather Bureau more directly useful to his particular needs.

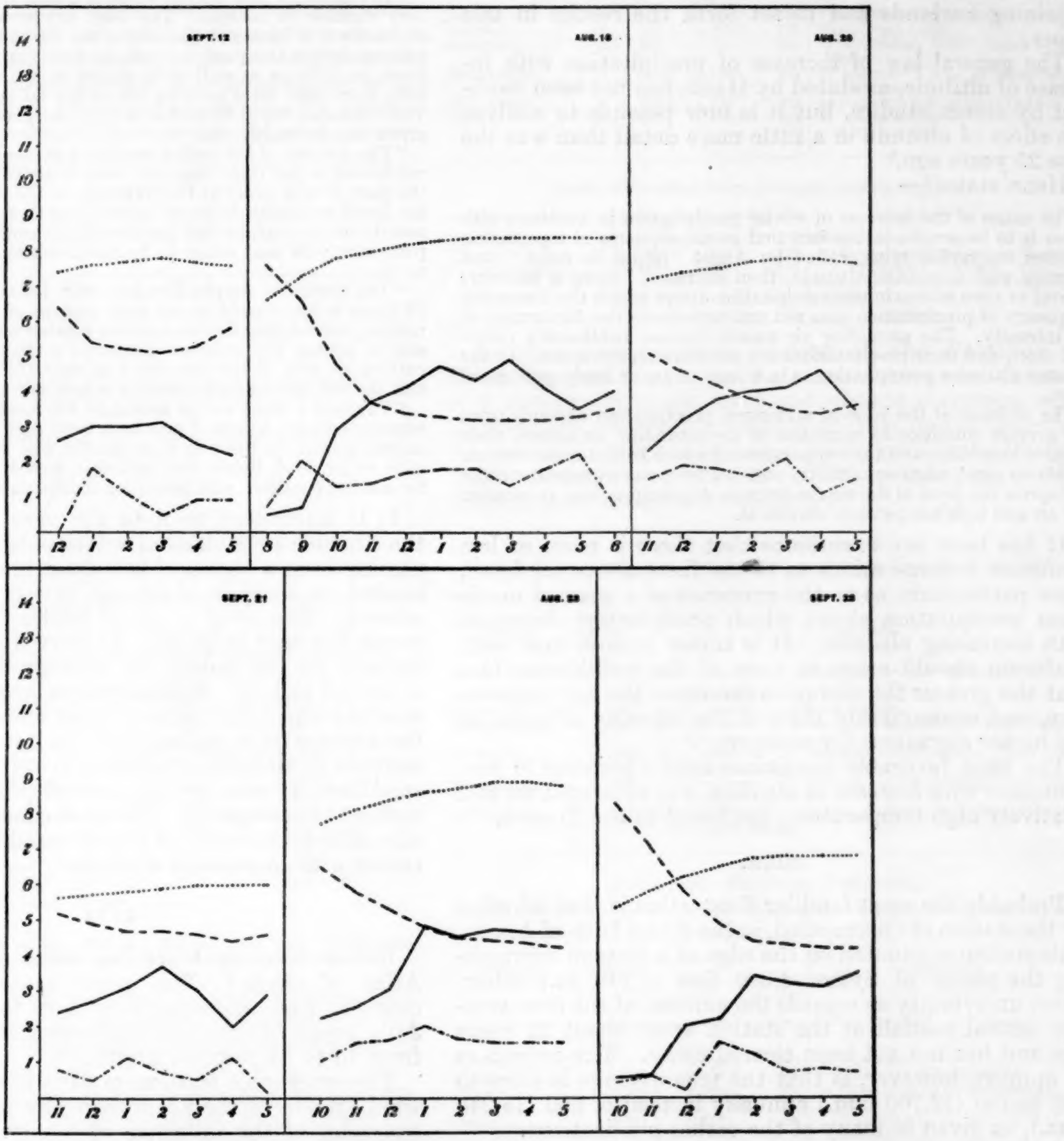


FIG. 2.—Graphs of values representing evaporation from porous-cup atmometers (full lines), air temperature (dotted lines), relative humidity (dash lines), and "radiation" (dash-dot lines).

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INCREASE OF PRECIPITATION WITH ALTITUDE.[1]

By ALFRED J. HENRY, Meteorologist.

[Dated: Weather Bureau, Washington, Jan. 11, 1919.]

Thirty-odd years ago, when the irrigation of arid regions in southwestern United States was first seriously considered, much embarrassment was caused by lack of definite knowledge as to the increase of precipitation with increase of altitude.

For the sake of brevity, the relation between the increase in precipitation in connection with increasing altitude above sea level will be referred to hereafter in this paper as the "precipitation-altitude relation."

In the absence of gage records, various methods have been used to interpolate the rainfall of higher altitudes, the most common one being based on considerations of vegetal cover and topography.

[1] Read before the Association of American Geographers, Baltimore, Md., Dec. 27, 1918.

In recent years an organized effort has been made by the United States Weather Bureau to extend available information as to the depth of precipitation, especially snow, in the higher elevations in the United States, mainly west of the 100th meridian. In various other ways the number of gauge records for elevated stations has increased. Since a more comprehensive knowledge of the subject will be immensely useful and practical, it is proposed to make a brief study of these new records and existing old records in connection with those of the adjoining lowlands and to set forth the results in this paper.

The general law of increase of precipitation with increase of altitude, as stated by Hann, has not been modified by recent studies, but it is now possible to analyze the effect of altitude in a little more detail than was the case 25 years ago.[2]

Hann states[3]—

> The cause of the increase of winter precipitation in moderate altitudes is to be sought in the fact that in consequence of topographic features orographic rains, called by Angot "pluies de relief," first increase with increasing altitude, then decrease. There is therefore a level or zone of maximum precipitation above which the increasing frequency of precipitation does not counterbalance the diminution in its intensity. The ascending air masses become continually colder and drier, and their precipitations are therefore always scant. In the greatest altitudes precipitation is in a form of fog or finely pulverized snow.
>
> The altitude of the zone of maximum precipitation depends upon the average condition of saturation of the ascending air masses, their relative humidity, and the temperature at which condensation begins. In winter great relative humidity and low temperature together unite to depress the level of the maximum zone of precipitation; in summer dry air and high temperature elevate it.

It has been my experience that there is more or less confusion in some minds as to the facts above set forth, more particularly as to the existence of a zone of maximum precipitation above which precipitation decreases with increasing altitude. It is rather curious how such confusion should arise, in view of the well-known fact that the greater the elevation the lower the air temperature, and consequently the less the capacity of space at the higher elevations for moisture.

The most favorable conditions for an increase in precipitation with increase in altitude, viz, saturated air and relatively high temperature, are found in the Tropics.

INDIA.

Probably the most familiar illustration is that afforded by the station of Cherrapunji, in the Khasi Hills of Assam. This station is situated on the edge of a plateau overlooking the plains of Sylhet 4,000 feet (1,219 m.) below. Some uncertainty as regards the amount of the true average annual rainfall at the station arose about 25 years ago and has not yet been cleared away. The consensus of opinion, however, is that the true average is close to 500 inches (12,700 mm.) annually instead of 600 (15,240 mm.), as given in many of the earlier publications.

For our purpose it may be placed at 500 inches (12,700 mm.) and the average of the plains below at 100 inches (2,540 mm.). Accordingly, we have an increase of 400 inches in a vertical distance of 4,000 feet, or at the rate of 100 inches per thousand feet (830 mm. per 100 m.). This extraordinary increase must be considered as a purely local phenomenon due largely to the high temperature and moisture content of the air and the abruptness of the slope up which it is forced.

So far as known the natural conditions in no other part of the world are so favorable for a very great increase in the rainfall with increasing altitude, except, perhaps, on the western Ghats and in portions of the Hawaiian Islands.

I quote the following from an abstract of a paper on "The Tata Hydro-electric Power-supply Works, Bombay," by R. B. Joyner, published in *Nature*, London, Nov. 21, 1918, pp. 236–7:

> "The monsoon rain on the western Ghats, though always heavy, is very variable in amount. The least annual amount during the last 48 years was 82 inches on the edge of the Deccan plain, and the greatest amount during the past 11 years, in which special gauges have been fixed, on hilltops as well as in plains is 546 inches, which fell in a little more than three months, 460 inches falling in about two months. The minimum fall of 82 inches is very exceptional, and the maximum given may be equally so. * * *
>
> "The amount of 546 inches measured at one hill station in the lakes catchment is not more than has been measured in two or three out of the past 50 odd years at Cherrapunji, in the Assam Hills, which has the heaviest rainfall hitherto known; but there rain falls during seven months of the year, so that the amount measured for this work for that particular year may claim to be the heaviest rainfall ever yet measured.
>
> "The works [to supply Bombay with 100,000 horsepower for 10 or 12 hours a day during about nine months of the year] are probably unique, considering the very heavy rainfall and the very steep rocky slopes, giving the greatest discharge perhaps ever recorded. The catchment area of the two lakes is only 16½ square miles, while of this the full lakes area is about 7½ square miles. * * *
>
> "The water after use is available for irrigation, so valuable in a country without a drop of rain for a large part of the year. [Thus the monsoon rains in three or four months will supply the coast people with water, food, lights, raw materials, power for manufacture, power for making fertilizer, and power for transportation.]"

It is interesting to note the very striking change in the altitude-precipitation relation which takes place in passing from a region of moist air, mostly under cyclonic control, to a region of dry air, mostly under anticyclonic control. The west coast of Africa below latitude 20° South is a case in point. At Port Nolloth, on the coast, latitude 29° 16′ South, the average annual precipitation is but 2.7 inches. At Klipfontein, about 45 miles inland, near the top of the plateau, at an elevation of 3,084 feet, the average is 9 inches, and the rate of increase with increase in altitude is therefore barely 2 inches per thousand feet, (17 mm. per 100 meters), as compared with 100 inches at Cherrapunji. The west coast of South America also affords examples of a very small increase in precipitation with increase in altitude.

JAVA.

Rather recently there has come to hand a Rainfall Atlas of Java.[4] This work contains tables of the monthly and annual precipitation for 1,061 stations in Java, many of the series of observations covering periods from 15 to 33 years in length.

The orographic features of Java in connection with the wind system of the island conspire to produce excellent examples of the influence of topography upon rainfall. The elevated regions of the island are found in the central part, with a general east-west trend. The mountain system is not continuous, but consists rather of a large number of more or less isolated volcanic summits ranging in altitude from 1,000 to 3,000 meters (3,281 to 9,842 feet), only a small number of which exceed 3,000 meters. On the slopes of these summits and the ridges radiating therefrom the streams of the island take their rise, flowing generally directly to sea. The northern coastal plain

[2] Two neighboring places with the same total rainfall may differ considerably in individual months. Thus in Essex, England, Halstead at 139 feet above sea level gets more rain in months with over 50 mm., but less in months with under 25 mm., than does Ridgewell at 269 feet. (F. J. Gurney, M. O. Circ. 13, June 23, 1917, pp. 3-4.)—C. F. B.

[3] Lehrbuch der Meteorologie, 3d edition, Leipzig, 1915.

[4] Results of Rainfall Observations in Java, by Dr. W. Van Bemmelen, Batavia, 1914. B. C. Wallis has written an illuminating discussion of the rainfall of Java in the Scottish Geographical Mag., 1917, 33: 108–119. Maps, diagrs., bibliog. There is also a good illustrated review of this by Prof. Mark Jefferson in Geogr. Rev., New York, June, 1918, 5: 492–495.

is much more extensive than the southern, and the streams are more important, both physically and economically.

There are two rainfall seasons—first, that of the northwest monsoon, October to March; and, second, that of the southeast monsoon, April to October. In April and May the wind is variable; June, July, and August are the months of the settled southeast monsoon. The change to the northwest monsoon usually takes place in October, at times as early as September or as late as November. Although the rainfall of the northwest monsoon is greater than that of the southeast, yet points at sea level on the north coast receive less rainfall than points at sea level on the south coast, especially in the western part of the island. This is probably due to orographic control.

As might be expected, the island presents many exceptions to the general precipitation-altitude relation. Some

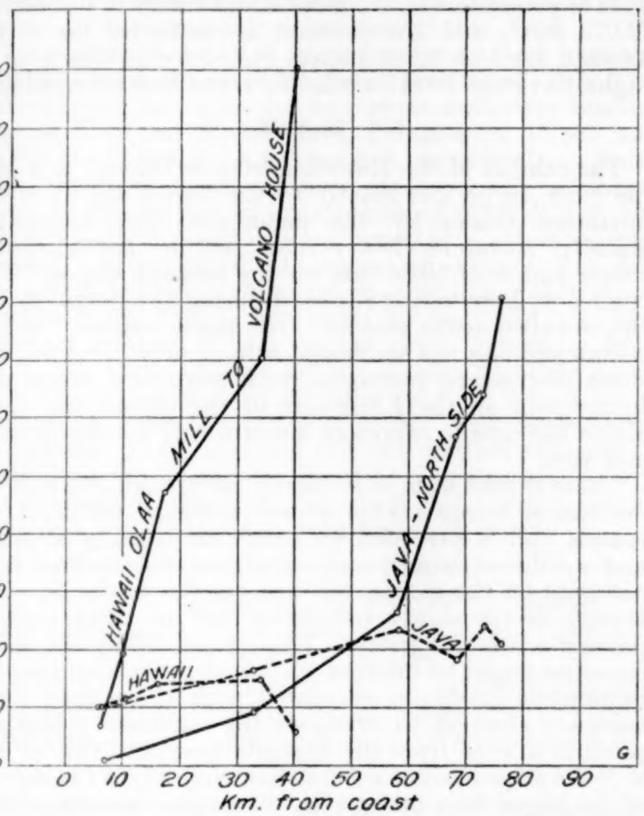

FIG. 1.—Precipitation—altitude relation, Java and Hawaii. Solid lines—Profile of sections. Dashed lines—Relative amount of precipitation in percentages.

of these exceptions will doubtless be better understood upon a fuller disclosure of the details of exposure to the rain winds, and also of the effect of the general relief of the island upon the rainfall.

A cursory examination of the data seems to indicate that the northwest or winter monsoon does not cast a marked rain shadow over the leeward slopes. The rain shadow of the summer monsoon is much better defined.

I have selected from the records in Van Bemmelen's work those which serve to form a rainfall profile across the western portion of the island, beginning with the station Batavia at sea level—annual mean 1,829 mm. (Fig. 1.) Considering that amount as unity, or 100 per cent, I have computed the relative amounts at points with increasing elevation as one passes inland from the coast and approaches the divide. No observations are available for the divide, but I have formed a second profile from the south coast leading inland to as near the divide as the available records permit.

The results are given in Table 1:

TABLE 1.—*Java rain profile, west end.*
North side—beginning at Batavia. See Figure 1.

Stations.	Years of observation.	Altitude.	Precipitation. Average amount.	Precipitation. Relative amount.	Location.
		m.	*mm.*		
Batavia	33	7	1,829	100	7 kilometers south from north coast.
Depok	33	95	3,214	176	North coast plain.
Buitenzorg	33	266	4,304	235	15 kilometers NNE. Salak (2,210 meters).
Bendoengan	18	568	3,319	182	15 kilometers NW. of Pangerango (3,020 meters).
Pasir Pogor	18	640	4,430	242	5 kilometers NE. of Salak (2,210).
Tapos	18	806	3,798	208	11 kilometers NW. of Pangerango (3,020 meters).
South side—Residency preanger regentschappen.					
Tendjoresmi	11	100	3,000	100	Near the south coast.
Tjipari	12	750	3,788	126	8 kilometers north from south coast.
Pandan Aroem.	11	850	4,154	138	4 kilometers south of Kendeng (1,370 meters) and 26 kilometers NNE. from coast.

Another cross section starting in the Province of Pekalongan at the city of the same name at an altitude of 9 meters above sea level and distant therefrom only 2 kilometers, proceeding south-southeast up the slopes of the mountain ridge dominated by two summits, Prahoe (2,565 meters) and Slamak (3,427 meters), gives the relative amounts shown in Table 2:

TABLE 2.—*Java rain profile.*
North side—beginning at Pekalongan, and proceeding south-southeast.

Altitude.	Relative precipitation.	Location.
Sea level	100	At Pekalongan.
160 meters	182	South border of north coast plain.
500 meters	265	6 kilometers NW. Beser (1,585 meters) west slope Sengkarang Valley.
700 meters	291	10 kilometers NE. Prabata (1,572 meters), East Slope Koepang Valley.
720 meters	317	9 kilometers NE. Prabata (1,572 meters), East Slope Koepang Valley.
1,500 meters	266	2 kilometers SSE. Prabata, 5 kilometers N. Ragadjembangan (2,176 meters).

South Side—Residency Banjoemas.

Station.	Altitude.	Precipitation. Mean annual.	Precipitation. Relative amount.	Location.
	m.	*mm.*		
Tjilatjap	6	3,869	100	On the coast.
Djamboe	21	2,678	69	On the plain of Djatilawang.
Tjilongak	217	4,866	126	14 kilometers SSE. Semboeng (1,463 meters).
Kranggan	311	8,305	215	6 kilometers SSW. Semboeng (1,463 meters).

The observatory station Kranggan, with but seven years' observations, gives the greatest average precipitation in Java. It is situated 45 kilometers from the south coast on the headwaters of two small streams, evidently close to, but to the south of, the main divide between the north and the south drainage, respectively.

The elevation of the station and the adjacent topography do not seem to warrant the expectancy of so great a rainfall. Although heavy rains occur in all months of the year, the season of greatest rain is in the northwest monsoon; the maximum falls in October, 1,200 mm.

(47.2 in.), and the minimum in June, 322 mm. (12.1 in.). The presence of Semboeng, 5 kilometers NNE., does not shed any light upon the cause of the very heavy precipitation. The station Djelegong, also on the southern slope, altitude 747 meters (2,451 feet), about 30 kilometers ENE. of Kranggan, and 13 kilometers east of Slamet, 3,427 m. (11,243 feet), has an annual mean precipitation of 6,089 mm. (239.72 in.). The minimum at this station falls in July and August when the southeast monsoon is at its height. The maximum falls in January and December, thus indicating that the northwest monsoon does not cast a well defined rain shadow to leeward.

I have computed the average annual precipitation for six residencies in Java, in zones of increasing altitude beginning at sea level. The altitude intervals are as follows: 0–100 meters, 101–200 meters, 201–300 meters, 301–500 meters, 501–750 meters, 751–1,000 meters, 1,000 + meters.

When the number of stations in any zone is small—less than 6—the minimum weight should be given the averages; for example, under Residency Pekalongan, zone 1,000 + meters, appears the average 5,061 mm. (199.2 in.). This value was computed from the records of but two stations, one of them had an average of 3,591 mm. and the other 6,531 mm., combined mean 5,061 mm. as given. In this case both stations were at practically the same elevation, but one of them was favorably situated to receive heavy rains during the northwest monsoon, while the other was less favorably situated.

In general, there is an increase from sea level inland up to the highest points for which observations are available. As might be expected, there are many exceptions to the general rule which must be explained on the ground of local environment and exposure to the rain winds. Table 3 summaries the results.

TABLE 3.—*Increase of precipitation with altitude, Java.*

NORTH SIDE.

Altitudes in meters.	Residency Batavia.			Residency Pekalongan.			Residency Semarang.		
	Number of stations.	Average.		Number of stations.	Averages.		Number of stations.	Average.	
		Altitude.	Annual precipitation.		Altitude.	Annual precipitation.		Altitude.	Annual precipitation.
		M.	*Mm.*		*M.*	*Mm.*		*M.*	*Mm.*
0–100	27	31	2,001	60	27	2,474	68	21	2,426
101–200	4	154	3,326	11	134	3,094	3	154	3,524
201–300	5	235	3,530	8	265	4,062	3	266	2,982
301–500	4	432	3,551	10	399	4,363	12	426	3,059
501–750	13	606	3,919	8	628	5,012	11	606	3,372
751–1,000	4	839	4,364	7	841	5,121	6	813	3,604
1,000+	3	1,087	4,593	2	1,516	5,061	4	1,083	4,189

SOUTH SIDE.

Altitudes in meters.	Residency Preanger Regentschappen.			Residency Banjoemas.			Residency Kediri.		
	Number of stations.	Average.		Number of stations.	Average.		Number of stations.	Average.	
		Altitude.	Annual precipitation.		Altitude.	Annual precipitation.		Altitude.	Annual precipitation.
		M	*Mm.*		*M.*	*Mm.*		*M.*	*Mm.*
0–100	7	21	3,205	15	30	3,229	29	77	1,836
101–200	3	134	3,811	5	148	4,263	12	142	1,855
201–300	6	269	2,923	3	248	4,347	7	251	2,422
301–500	11	400	3,552	1	311	8,305	7	381	2,581
501–750	24	632	2,879	1	747	6,089	7	591	3,437
751–1,000	22	831	3,399	1	956	4,682	2	757	3,918
1,000+	29	1,366	3,392	4	1,082	4,542	2	1,102	5,790

The compilation in Table 3 shows that the average rate of increase on the north side up to 400 meters (1,312 feet) is 333 mm. per 100 meters, or at the rate of 40 inches per 1,000 feet. The rate diminishes to the eastward of Batavia, and is also smaller on the south coast except when the phenomenal record of Kranggan is used.

Two of the south side residencies show a high average for coast stations, while the third—Kediri—shows the opposite.

The altitude of the zone of maximum precipitation on the north side of the island is not far from 1,000 meters (3,281 feet). On the south side it seems to be lower, although the data are not conclusive. In the Preanger Residency a large number of records for elevations 500 to 1,000 meters are available. These records show a considerable decrease in precipitation from an average altitude of 400 meters (1,312 feet) to an average of 632 meters (2,073 feet), and the decrease is continued up to the average level of 1,366 meters (4,482 feet)—the zone of highest average level for which observations are available.

HAWAII.

The rainfall of the Hawaiian Islands belongs to a simple type, being due mostly to the forced ascent of the northeast trades by the mountains they encounter. Usually, therefore, heavy rains fall on the windward slopes and very little rain on the leeward slopes. This condition, however, is reversed during the prevalence of the so-called Kona storms. The name "Kona" in Hawaiian signifies the southwest side or slope, and because these storms are associated with southwest winds and heavy rain on the Kona side of the islands the name Kona has cme to represent a storm with southerly wind and rain.

These storms seem to be merely the trough of a cyclonic depression whose center moves eastward north of the islands and is preceded by southeast shifting to south and southwest winds, and sometimes tremendous rains not only on the slopes, but also on the lowlands. The trough moves slowly occupying two or three days in passing across the group. They are of infrequent occurrence, as might be inferred when it is considered that the barometric gradients associated with them must be of sufficient strength to overcome the northeast trades and produce a wind from the opposite quarter. One or two well-developed Kona storms, however, affect the rainfall of the island very materially, since more rain may fall in a single storm than usually falls in a year, especially on the southwest slopes. Very striking contrasts are thus afforded in the annual precipitation of a series of years.

In considering the precipitation-altitude relation in the Hawaiian group, I have chosen but two examples, the first on the island of Oahu and the second on Hawaii.

There are two mountain systems on Oahu, viz, the Koolau Range in the northeast, extending the full length of the island, the crest being approximately 3.6 miles (6 km.) inland. The Waianae Range extends along the southwest side parallel to the Koolau Range. A cross section across the Koolau Mountains in the vicinity of Honolulu is easily constructed. (See fig. 1.)

Beginning at Waimanola, at sea level, with an annual average of 41 inches (1,041 mm.) considered as unity, the following relative amounts are obtained:

Waimanalo, 25 feet	100
Tantalus Peak:	
1,665 feet	410
1,360 feet	250
Kaliula Peak, 1,200 feet	220
Honolulu (W. B.), 99 feet	60
Honolulu naval station, 6 feet	50

The distance in an air line from sea level at Waimanolo across the range to sea level at Honolulu is about 12 miles (19 km).

Tantalus Peak and Kaliula are on the leeward slope but near the crest.

The rainfall on Tantalus Peak at an altitude of 1,665 feet (507 meters) is four times as great as at sea level about 6 miles (10 km.) distant, practically the same relation that holds at Cherrapunji. Descending on the lee side of the mountains the rainfall rapidly diminishes to about half of the value it has at sea level on the windward side of the range.

The rainfall at Makapuu Point, the extreme southeastern tip of the island, although the measurements are made at an elevation of 570 feet (174 meters) above sea level amounts to only 15 inches per annum on the average. This is explained by the fact that there is no mountain background for that part of the island.

The second chain of stations has been taken from the records of the Island of Hawaii. This island, it will be remembered, contains the two great mountain masses, Mauna Kea and Mauna Loa, altitudes of 13,805 and 13,675 feet (4,208 and 4,168 meters) respectively. Rainfall measurements have been made on the southeast slope of the former at an altitude of 6,450 feet (1,966 meters) and the record covers a period of a little more than 6 years. As compared with the record at sea level at Hilo less rain falls at the elevation above mentioned than at sea level and this fact is confirmed by the records of the chain of stations a little to the south extending from Olaa Mill, north latitude 19° 39′, 4 miles from the coast, to Volcano House, about 25 miles (40 km.) inland, at an altitude of 3,984 feet (1,214 meters). The geographical coordinates of the stations and the relative amounts of rainfall on the average of about 15 years record, except for the station Glenwood, for which but a single year is available, will be found in the statements below:

	North latitude.	West longitude.	Elevation.	Remarks.
	° ′	° ′	*Feet.*	
Olaa Mill	19 39	155 0	210	4 miles from ocean.
Kurtistown	19 37	155 2	640	7 miles from ocean.
Olaa (17 miles)	19 35	155 3	1,530	11 miles from ocean.
Glenwood	19 26	155 10	2,300	21 miles from ocean.
Volcano House	19 26	155 16	3,984	25 miles from ocean.

Considering Olaa Mill average annual precipitation 148 inches (3,759 mm.) as unity, the relative annual amounts up to an altitude of 3,984 feet (1,214 meters) are as follows:

Olaa Mill	100
Kurtistown	115
Olaa (17 miles)	140
Glenwood	145
Volcano House	59

The zone of maximum precipitation in this cross section is below 1,000 meters (3,281 feet) and in general is at a low elevation elsewhere in Hawaii. The precipitation at a point on the southeastern slope of Mauna Kea at an altitude of 6,450 feet (1,966 meters), before referred to, is but 67 per cent of that at Hilo at sea level. A second high level station at practically the same altitude but slightly farther west on the divide between Mauna Kea and Mauna Loa gives a still smaller percentage, viz, 23, of that at Hilo. The zone of maximum precipitation appears to be between 350 and 400 meters (1,148 and 1,312 feet), so far as can be determined from existing records, although more extended observations will probably place it slightly below 1,000 meters.[5]

An eleven-year record at Hakalau (Mauka) 1,200 fee (365 meters) gives an annual average of 280 inches (7,112 mm.) as compared with 142 inches at Hilo.

The southwest slope of Hawaii as represented by the station at Hilea about 2 miles from the coast and at an elevation of 310 feet (95 meters) affords an interesting example of the influence of southwest storms on the rainfall. In 1915 the rainfall of the nine months January to September was 19.12 inches (483 mm.). In November of the same year, due to the prevalence of Kona storms, the rainfall was 20.46 inches (509 mm.) and in December 13.31 inches (338 mm.). Again in 1916, 15.98 inches (406 mm.) fell in January as against 0.10 inch (2.5 mm.) in the same month of the previous year. Nine inches (229 mm.) of rain fell in two days, due to the prevalence of a Kona storm.

There has recently come to notice an account of a rainfall record kept on the summit of Mount Waialeale, elevation 5,075 feet (1,546 meters), Island of Kauai, Territory of Hawaii (Science, Nov. 23, 1917).

The mean of 5 years' observations at this place gives ar annual average of 518.4 inches (13,157 mm.), a larger amount than has been recorded elsewhere in the Hawaiian group. Mount Waialeale is the highest point on the island and is situated very near its geographic center. On the windward side there are not sufficient observations to determine the increase in precipitation per thousand feet, but it must be much greater than that found in other islands of the group. A station near the windward coast, Kilauea, elevation 342 feet (104 meters), has an annual average of 69.28 inches (1,758 mm.), an amount considerably less than is found at sea level on Hawaii. If further years of observation should sustain the high average maintained during the five years 1912–1916, Mt. Waialeale will doubtless take rank as one of the rainiest places on the globe. The conclusion as to the height of the zone of maximum precipitation on Hawaii evidently does not apply to the Island of Kauai.

WEST INDIAN REGION.

Jamaica.—The Blue Mountains lie athwart the northeast trades and should afford good examples of the increase of precipitation with increase of elevation. The rainfall régime of the island is by no means simple, there being two distinct maxima, one in May and June, the other in October.

Tropical disturbances which may visit the island in the period July to November are almost invariably attended by very great rainfall, hence the occurrence of a tropical storm in any one of the above-named months has the effect of changing the month of maximum rainfall to the month in which the tropical storm occurred. Shallow cyclonic depressions in the winter months are also attended by heavy downpours of rain.

The heaviest rainfalls on the northeast coast and the average for that part of the island is, in round numbers, 125 inches (3,115 mm.). Passing inland toward the Blue Mountain Range an average fall of 227 inches (5,766 mm.) is found not far from the coast at an altitude of 600 feet (183 m.). Still farther inland the measurements made at Blue Mountain Peak, altitude 7,423 feet (2,262 meters), give 175 inches (4,445 mm.) as the average, an increase of

[5] Martin and Pierce in Water Supply Paper 318, p. 462, place the elevation of the zone of maximum precipitation on Hawaii at about 2,500 feet (762 m.).

but 50 inches (1,270 mm.) in a vertical distance of slightly more than 7,000 feet (2,134 meters).

Porto Rico.—The rainfall régime of Porto Rico is much the same as that of Jamaica. The rainfall is heaviest on the eastern slope of the Luquillo Mountains in the extreme northeastern part of the island. From an annual average of 54.81 inches (1,392 mm.) on Vieques Island, off the northeast coast, the amount increases to 136 inches (3,454 mm.) at Luquillo, altitude 1,200 feet (366 meters), an increase of 82 inches (2,083 mm.); in 1,155 feet (351 meters).[6]

THE UNITED STATES.

Hitherto I have considered examples drawn from tropical or subtropical regions. Let us now consider examples from temperate latitudes, as the Pacific coast and Rocky Mountain States. The conditions under which the precipitation of atmospheric moisture occurs in this region are different from those which obtain in the trade-wind zones and the Tropics hitherto considered. The weather controls in temperate latitudes are almost exclusively cyclonic. It so happens that one of the chief centers of cyclonic origin in the Northern Hemisphere lies to the northwest of the Pacific coast States, and that during the cold season cyclonic control of the weather, especially in western Washington and western Oregon, and to a less extent along the northwestern coast of California, is practically continuous. There is, therefore, superposed upon the ascensional movement of the air due to the mountain systems which parallel in a general way the direction of the coast, an additional small vertical movement due to the cyclonic influence. Hence it is not surprising that the region of greatest rainfall in the United States is found on the Pacific coast.

Hitherto the data submitted have shown a progressive increase in the absolute amount of precipitation from sea level inland as higher elevations were reached. This rule must now be reversed, since the absolute amount of precipitation diminishes with distance from the ocean or other large body of water. Other things being equal, the heaviest precipitation in the United States should be found on the west slope of the Olympics of Washington and the coast range of California and Oregon; but other things are not equal, and, moreover, the absence of rainfall observations in the wettest localities in those ranges makes it impossible to confirm this belief by actual gage records.

The average annual precipitation on Tatoosh Island—a rock which stands 57 to 100 feet (17 to 30 meters) above the ocean level at the mouth of the Strait of San Juan de Fuca—is 88.78 inches (2,255 mm.). At Neah Bay, 7 miles east of Tatoosh Island, on the south shore of the Strait, the average annual precipitation is 108.31 inches (2,751 mm.). The heaviest precipitation of Washington is undoubtedly on the west slope of the Olympic Mountains, which occupy the greater part of the peninsula between the Pacific and Puget Sound. This mountain country is rugged, uninhabited, and measurements of precipitation on the mountain slopes are not available. In the absence of the definite measurements west of Puget Sound I was compelled to determine the rainfall profile as it crossed the Cascades and descended into the arid region of the Columbia River Valley. Three railroad lines cross the Cascades, each of them in a tunnel about 1,000 feet (305 meters) below the summit of the range. I have used the crossing of the Chicago, Milwaukee & Puget Sound Railway at Snoqualmie Pass and, in general, the line of stations following the Northern Pacific westward to Seattle and eastward into the valley of the Yakima and finally into the Columbia River Valley at Kennewick, Wash. The record of but a single year, 1916, has been used. The geographical coordinates of the stations and the relative amounts of precipitation, Seattle annual being considered as unity, appear in the table below.

	North latitude.		West longitude.		Elevation.	Precipitation.	
						1916	Relative amounts.
	°	′	°	′	*Feet.*	*Inches.*	
Seattle	47	38	122	20	209	34.61	100
Snoqualmie Falls	47	30	120	55	667	57.84	167
Cedar Lake	47	25	121	45	1,590	113.25	327
Snoqualmie Pass	47	25	121	25	3,000	96.48	280
Lake Keechelus	47	19	121	20	2,479	70.16	203
Lake Clealum	47	14	121	4	2,160	27.09	78
Ellenburg	46	59	120	32	1,577	10.27	30
North Yakima	46	36	120	30	1,076	7.22	21
Sunnyside	46	20	120	00	740	7.21	21
Kennewick	46	26	119	15	370	12.04	35

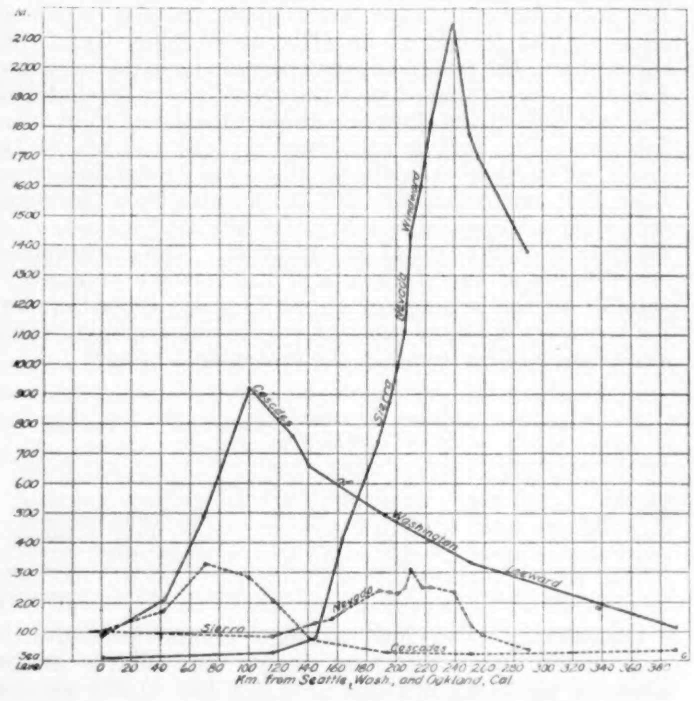

FIG. 2.—Precipitation—altitude relation, Western United States. Solid lines—Profiles of sections. Dashed lines—Relative amount of precipitation in percentages.

The zone of maximum precipitation in Washington and in many other parts of the world is at some distance to the windward of the mountains, as was pointed out by Hill for India many years ago. From the level at Snoqualmie Pass to Lake Clealum, where the rainfall begins to diminish sharply, the distance is 27 miles (43 km.). The diminution of precipitation on the leeward side of the Cascades of Washington does not appear to be so sharp as on the lee side of the Sierra Nevada in central California. The crest of the range at Snoqualmie Pass is 1,000 feet (305 meters) above the rainfall station. (See fig. 2.)

In Oregon the physiographic features are much the same as in Washington, although the mountains of the coast range do not reach the altitudes of the Olympics of Washington and no railway crosses the Cascades; hence a chain of stations crossing the mountains is not avail-

[6] Dr. O. L. Fassig in MONTHLY WEATHER REVIEW, 1909, 37: 982-986.

able. I have assembled, however, the data for the construction of a profile of the annual precipitation beginning at Tillamook, on the bay of the same name, ascending the coast range, thence descending into the Willamette Valley, and thence ascending to Government Camp, a station on the south slope of Mount Hood at an elevation of 3,897 feet (1,188 m.). The cross section is incomplete, but the best available. The geographical coordinates of the stations and the relative amounts of annual precipitation appear in the table below. Average values are used. Tillamook, with an annual average of 102 inches (2,591 mm.), considered as unity.

Stations.	North latitude.	West longitude.	Elevation.	Precipitation. Average.	Precipitation. Relative amounts.
	° ′	° ′	*Feet.*	*Inches.*	
Tillamook	45 27	123 51	20	102.0	100
Glenora	45 20	123 50	575	130.0	120
Forest Grove	45 21	123 5	220	51.0	50
Portland	45 32	122 41	75	44.5	44
Headworks	45 27	122 12	719	79.0	77
Welches	45 20	121 57	1,385	82.0	80
Government camp	45 18	121 51	3,890	86.0	84

California.—A very common example of the increase of precipitation with increase of altitude is afforded by the chain of stations along and near the Southern Pacific Railroad from Oakland, Cal., across the Sierra Nevada, descending thence to the dry region of the Great Interior Basin in Nevada and Utah.

Ten-year means have been computed for a chain of stations beginning at Oakland, Cal., and ending at Reno, Nev., and the results are given in the table below, and also appear in fig. 2. Oakland, the base station, is at sea level directly across the bay from San Francisco. The average annual precipitation is 24.30 inches (617 mm.).

Stations.	Elevation.	Relative amounts.	Stations.	Elevation.	Relative amounts.
	Feet.			*Feet.*	
Oakland	36	100	Towle	3,612	241
Sacramento	71	80	Blue Canon	4,695	304
Rocklin	249	121	Emigrant Gap	5,230	243
New Castle	956	140	Cisco	5,939	244
Auburn	1,363	165	Summit	7,017	223
Colfax	2,421	237	Truckee	5,820	118
Iowa Hill	2,825	229	Boca	5,531	83
Gold Run	3,222	226	Reno (Nev.)	4,484	35

Alexander McAdie shows that the average rate of increase on the west slope up to 1,500 meters is about 75 mm. per 100 meters; and from the summit down the east slope the decrease is 147 mm. per 100 meters of descent.[7]

According to the above table, the zone of maximum precipitation in the Sierra Nevada is somewhere near 1,500 meters (4,921 feet). The fact that it varies in altitude with different storms was brought to the writer's attention by an examination of the records of two heavy rainstorms in southern California in January, 1914, and 1916, respectively.

It may easily happen that the air in one storm is nearer to saturation than in another and this is probably the explanation of the difference in the relative amounts in the two storms. A second example of the precipitation altitude relation in California, consisting of but four stations, beginning at Fresno in the Great Valley of California and ascending the mountains near that place, follows:

	Altitude.	Precipitation (mean of 2 seasons).	Relative amounts.
	Feet.		
No. 1	230	11.40	100
No. 2	1,013	31.53	277
No. 3	2,441	31.63	278
No. 4	3,500	50.16	440

This group of stations is about 180 miles (290 km.) south of the Union Pacific group and in a region of less rainfall. The increase in precipitation on the west slope of the Sierra Nevada from the floor of the Great Valley to the 5,000-foot (1,524-meter) contour, according to Chas. H. Lee, is 8.5 inches per thousand feet (70 mm. per 100 m).[8] A. McAdie[9] shows that in southern California where the zone of maximum rainfall is much higher, the precipitation increases about 50 mm. per 100 meters (6 in. per 100 ft.) up to 2,500 meters.

The rate of increase of precipitation with increasing elevation is not so well marked east of the Sierra Nevada and the Cascade Ranges, but is still a characteristic of the high-level climate between the ranges above named and the Rocky Mountains.

Idaho.—The elevated regions of Idaho are in the eastern part of the State, particularly along the Montana-Idaho boundary. There is also a central plateau region whose general elevation slightly exceeds 5,000 feet (1,524 meters), with mountain ranges and isolated peaks considerably higher. The precipitation of this central plateau region and also of the southeastern plateau is light regardless of its altitude. While no measurements have been made in the mountain slopes, the central plateau records maintained at points between 5,000 (1,524 meters) and 7,000 feet (2,134 meters) elevation generally indicate an annual rainfall of less than 20 inches (508 mm.). The region of maximum precipitation, 35 to 45 inches (889 to 1,143 mm.) annually, is found on the western slopes of the Cabinet and Coeur d'Alene Ranges and probably also on the western slope of the Bitter Root Range. I am able to present the records of four stations beginning at Coeur d'Alene at the north end of the lake of the same name and extending to the village of Burke, 50 miles (80 km.) east-northeast of Coeur d'Alene and about 2,000 feet (610 meters) higher. The details of the stations appear in the table below:

Stations.	North latitude.	West longitude.	Elevation.	Precipitation. 1916	Precipitation. Relative amounts.
	° ′	° ′	*Feet.*	*Inches.*	
Coeur d'Alene	47 41	116 47	2,157	28.23	100
Kellogg	47 33	116 0	2,330	37.20	132
Wallace	47 25	115 55	2,728	47.26	170
Burke	47 32	115 47	4,082	46.20	164

These records, for 1916 only, show that with an increase in elevation of 1,925 feet (585 meters) there is an increase of 18.03 inches (458 mm.) in the annual precipitation. This increase corresponds roughly to an increase of 9.4 inches per thousand feet, or, in metric measures, 78 mm. in 100 meters.

The region here considered—the northern part of the State—has a fairly effective mountain background in the Cabinet and Coeur d'Alene ranges whose summits scarcely exceed 6,000 feet in altitude although individual peaks may be higher. This region is, moreover, in the

[7] Alexander McAdie, "The rainfall of California," Univ. Calif. Geogr. Pub., 1914, I:127-240, pls. 21-28. (Review, Science, 1914, n. s. vol. 40, pp. 29-30.)

[8] MONTHLY WEATHER REVIEW, 1911, 39: 1099.

[9] Loc. cit.

direct path of traveling cyclones which move inland from the Pacific and is, therefore, more favorably situated to receive generous precipitation than the regions farther to the southward.

A second line of stations leading from the Snake River Valley at Lewiston, altitude 757 feet (231 meters) in a southeasterly direction to the rolling country in Lewis County at general elevation of about 3,000 feet (914 meters) was made by using the records of the following named stations.

Station.	North latitude	West longitude.	Elevation.	Precipitation, 1916.
	° ′	° ′	Feet.	Inches.
Lewiston	46 25	117 02	757	17.49
Culdesac	46 23	116 42	1,520	20.62
Nezperce	46 13	116 19	3,082	23.45

The above records show that with an increase in altitude of 2,325 feet (709 meters) in a horizontal distance of about 40 miles (64 km.) precipitation for the single year of 1916 increased roughly 6 inches (152 mm.), or at the rate of 2.6 inches per 1,000 feet (22 mm. per 100 meters).

Utah and Colorado.—There is an increase in precipitation with increase of altitude on the southwest slope of the Wasatch Mountains, but sufficient data are not available to show definite results. At the Utah Experiment Station, maintained by the Forest Service in cooperation with the Weather Bureau, observations for two seasons June to September, inclusive, at altitudes between 8,000 and 10,000 feet (2,438 and 3,048 meters) show an increase of approximately an inch per thousand feet (8 mm. per 100 meters). The rainfall of 1915 at 10,000 feet (3,048 meters) elevation was, however, only 60 per cent of that of the previous year. It is interesting to note that stations at the foot of the Wasatch, elevation about 5,000 feet (1,524 meters), showed the same disparity between the rainfall of the years 1914 and 1915, the latter being exactly 60 per cent of the former on the average of four stations, thus showing a variation in the same sense at both low and high-level stations.

The precipitation observations at Wagon Wheel Gap Experiment Station, maintained by the two services above mentioned, afford information of great interest for a section of marked contrast in topography far removed from the ultimate source of moisture. At this station, detailed measurements of precipitation are made on the eastern slope of a mountain mass which rises from an elevation of about 8,400 feet (2,560 meters) in the valley of the Rio Grande to a little more than 11,000 feet (3,353 m.) at the top of the experimental area.

Records of precipitation are now available for a seven-year period at points which, for convenience, may be designated as follows:

	Altitude.	Average annual precipitation.
	Feet.	Inches.
No. 1	9,601	21.12
No. 2	9,609	20.31
No. 3	9,426	20.88
No. 4	9,434	20.24
No. 5	10,949	24.76
No. 6	[1] 11,200	25.59
No. 7	[1] 11,200	25.50
No. 8	[1] 11,500	26.64

[1] Approximate only.

Combining the stations in two groups, an upper and a lower, it is found that there is, roughly, an increase of approximately 3.3 inches per 1,000 feet (28 mm. per 100 m.).

East of the Rocky Mountains.—The highest point in the United States east of the Rocky Mountains is Mount Mitchell, N. C. Fortunately for our purpose, eight months, rainfall observations on the top of that mountain are available. The rain winds of North Carolina are mostly easterly and southerly. But at times they may be from any quarter. The mountain system of which Mount Mitchell is a part trends in a general northeast-southwest direction; consequently the full effect of the rain winds is experienced only when they are from the southeast. The labor of classifying the rainfall according to the direction of the wind is scarcely warranted by the probable value of the results. I have, therefore, used the full eight months' period during which the precipitation was measured on Mount Mitchell and compared the total amount with the totals for the corresponding period at lower levels. The results are set forth in the table below. The cross section is made from Hatteras on the coast to Mount Mitchell in an almost due east-west line, departing north or south therefrom only slightly when necessary to include a connecting station. The last-named station in the table is not a part of the cross section but is added because it is representative of a region of heavy rainfall with southeast winds. The station at Hot Springs, Tenn., is representative of the region to the northwest of the mountains and in their rain shadow. Newport and Knoxville, Tenn., are both west of Mount Mitchell and should show an increase in precipitation with southwest winds. Both stations have slightly greater rainfall than was recorded at sea level in about the same latitude. The mountain effect at points west of Mount Mitchell is apparently very small.

Stations.	North latitude.	West longitude.	Elevation.	Precipitation.	
				Total.	Relative amounts.
	° ′	° ′	Feet.	Inches.	
Hatteras	35 15	75 40	37	35.70	100
Greenville	35 37	77 22	75	29.92	84
Raleigh	35 45	78 37	390	33.76	95
Ramseur	35 45	79 39	442	34.01	95
Salisbury	35 40	80 28	764	47.95	134
Statesville	35 47	81 53	950	54.89	154
Morganton	35 45	81 41	1,135	47.29	132
Marion	35 41	82 1	1,425	51.86	145
Mount Mitchell	35 43	82 18	6,711	81.90	230
Newport, Tenn	35 58	83 12	1,110	36.62	103
Knoxville, Tenn	35 56	83 58	997	36.53	102
Hot Springs, Tenn	35 53	82 49	1,326	31.74	[1] 89
Rock House, N. C	35 0	83 10	3,000	90.27	[2] 253

[1] Western foothills. [2] About 80 miles southwest of Mount Mitchell.

SUMMARY.

The main features of the precipitation-altitude relation are essentially as follows:

1. The trend of the mountains must be in such a direction as to cause an ascent of the air masses which encounter them. Mountain systems whose axes are parallel, or nearly so, with the direction of the rain winds cause little or no increase in precipitation.

2. The inclination of the slope of the mountain is of great importance; the steeper the slope, other things being equal, the greater the precipitation. The quantity of rain or snow which falls anywhere is also conditioned upon the initial temperature and relative humidity of the air at the beginning of the ascent. Obviously, it also depends, in no small degree, upon the duration of

the winds from the rain quarter, or, in other words, upon the rate of movement of the atmospheric disturbance with which the rain winds are associated.

3. The altitude of the zone of maximum precipitation appears to vary slightly with latitude, being lowest in the Tropics—a little less than 1,000 meters—and highest in temperate latitudes, say, between 1,400 meters and 1,500 meters. It has also a seasonal variation, being highest in summer and lowest in winter.[10]

ALTITUDE RELATIONS OF RAINFALL IN FRANCE.

By E. MATHIAS.

[*Abstract:* "La pluie en France, etc." C. R. Paris Acad., 1919, 168: 105-108; 239-242.]

The precipitation-altitude relation in France may be expressed closely with the formula, $R=R_1+kA-k'A^2$, in which R represents the rainfall in millimeters at altitude A (in meters), R_1 the rainfall at a lowland station, k the coefficient of increase with altitude, and $k'A^2$ a term to take care of the decrease of rainfall above a certain elevation. For the Puy du Dome, and probably for the rest of France, k' is 1/20,000; thus, the formula becomes, $R=R_1+kA-\frac{1}{2}\ (A/100)^2$. On a map of France the author shows the values of k for each Department. k varies uniformly with latitude, ranging from 0.5 in the Pyrenees (lat. 43°) to 1.2 in the north (lat. 50°).—C. F. B.

THE CONSERVANCY WEATHER AND FLOOD WARNING SERVICE.

[From The Miami Conservancy Bulletin, Dayton, Ohio., Jan., 1919, vol. 1, No. 6, pp. 93-94.]

During the construction of the flood-prevention works it is of vital necessity that the District be informed as much in advance as possible of even slight flood stages in the river. There is much construction equipment, such as drag lines, railway tracks, locomotives, pumps, and motors, which must be used in or near the river bottoms, and failure to protect it from floods would mean very serious loss and delays. It also is desirable that the people of the valley receive all possible advance notice of any floods that may occur before the flood prevention works are completed, so that they may not again be taken unawares as in 1898 or 1913.

Perceiving the necessity of this, the Conservancy District in 1913 established a flood-warning service, under the direction of Mr. Ivan E. Houk. At that time there were only 15 stations in the Miami watershed where accurate measures of rainfall were made, and only three where careful measures of the river stages were made. Steps were at once taken, in cooperation with the United States Weather Bureau, to increase the number of these stations. The Government and the District together established four new combined rainfall and river stations; the District alone established eight combined stations and 13 river stations; and the Weather Bureau alone established 10 new rainfall stations. Thus the river stations were increased from 3 to 25 and the rainfall stations from 15 to 37. These are scattered throughout the Miami Valley, and by means of daily observations a close watch is kept on river stages and rainfall. In ordinary weather these observations are transmitted weekly to the district forecaster, but in times of storm or impending flood they are sent in by telephone or telegraph as often as is necessary. The forecaster may have to get up at midnight or at 1 or 2 o'clock in the morning to receive them and, in turn, to arouse the Conservancy engineers and other people whose property may be threatened.

The flood-warning service is as valuable in preventing unnecessary expense and alarm as it is in giving alarm when danger really impends. The memory of the 1913 flood is still fresh in people's minds. On January 31 and March 27, 1916, for instance, when the weather and river conditions seemed ominous, many would have moved out of their houses, farmers would have moved their livestock, construction companies their equipment, and merchants their stocks of goods, if they had not been assured that such steps were unnecessary. On the first of these dates two of the Conservancy engineers devoted their entire time all through the day and following night to answering telephone calls regarding river conditions. Two men of the United States Weather Bureau were also on duty from early morning until late at night answering such calls, which totaled about 1,600 in number. These inquiries came from all parts of the valley, from Piqua on the north to Hamilton on the south. At the same time an engineer experienced in flood fighting was sent to each of the cities where conditions seemed dangerous, to work with the local officials in taking such steps as might be necessary.

An instance of the value of such service in property conservation is the case of the Esterline Co., of Lafayette, Ind. This company had only 4 or 5 hours' notice of the flood in 1913, but in that time it moved from its buildings about $100,000 worth of merchandise, and all of its records, office furniture, and fixtures. The belting was removed from the machinery, which was then heavily coated with grease. By these precautions the company prevented an estimated loss of $60,000.

It is evident that such a service may well be the means of saving life as well as property by warning people who live on low ground to move when dangerous floods impend.

It will be clear from what has been said that the service of the flood-warning bureau is of great value, both to the Conservancy district in its work and to the people of the valley, and that compared with its value it is very inexpensive. A considerable part of this expense, moreover, is borne by the Federal Government.[1]

ADDITIONAL NOTE.

By R. FRANK YOUNG, Meteorologist.

[Dated: Weather Bureau, Dayton, Ohio, Feb. 10, 1919.]

The Miami River at Dayton has not reached the flood stage since the destructive flood of March 25-28, 1913, the nearest approach to flood since the latter date being on January 31, 1916, when it reached a stage of 14.7 feet.

The flood stage at Dayton is 18 feet, but as the levees afford protection to about 5 feet above this there is no real danger to the city till the water rises above 22 feet. It has been the experience of the Weather Bureau office, however, that a period of unusually heavy rains, with a rise to 12 feet or above causes much anxiety among the people living in the lower districts, and this may easily develop into something approaching a panic by the spreading of false rumors as to warnings. The telephone is, of course, an indispensable means of disseminating information at such a time, but in some instances the two telephones in use proved wholly inadequate to meet the

[10] A very comprehensive discussion of the precipitation-altitude relation for the British Isles will be found in a paper by Salter, C. The Relation of Rainfall to Configuration. (London Institution of Water Engineers. 1918, 37 pp., 2 pl.)

[1] See also, W. A. Drake, "The Miami Conservancy Flood Prevention Plan," Sci. Am., Mar. 22, 1919, pp. 282-283, 299-300, 5 figs.

requirements, and it is most likely that the fact that many people were unable to get in communication with this office tended to increase the excitement. The best means of meeting a situation of this kind is the issue of a short bulletin on the ordinary forecast card, which is given wide distribution in the city by mail carrier in the early morning delivery or in the afternoon, as conditions warrant. By multigraph process 2,000 or more of these bulletins can be prepared in a few minutes. In this way we have been able to reach the public more effectually than by telephone, and to do so several hours before the afternoon papers are issued.

It is exceedingly difficult to give timely warnings of floods in a river the size and character of the Miami because of the short interval of time between rainfall and the resulting crest stage in the river, which is approximately 12 hours in the upper and 18 hours in the lower stream. This was most clearly brought out in July, 1915. A heavy rainstorm occurred over the watershed on July 7, most of the rain falling between 8 p. m. and midnight. The crest stage from this rain was reached at Piqua, 40 miles above Dayton, about 11 a. m. of the 8th, and the river at Dayton had risen to within a foot of the highest stage by 2 p. m. of the 8th, although it continued to rise slowly till about midnight.

GENERAL CLASSIFICATION OF METEOROLOGICAL LITERATURE.

By CHARLES F. BROOKS, Meteorologist.

[Dated: Weather Bureau, Washington, Mar. 5, 1919.]

The following general classification of meteorological literature was evolved for the purpose of having a logical, simple, and easily remembered system for filing notes, pamphlets, and references. It is the outgrowth of the use of the Dewey Decimal System, of that in the International Catalogue of Scientific Literature (section F, Meteorology), and, finally, of a decimalized edition of the latter proposed by the late Eleanor Buynitzky of the Weather Bureau Library.[1] For an individual, the Dewey Decimal System is unduly detailed and cumbersome. To use this system it is necessary to refer to the classification and its index constantly while filing material. Furthermore, for appropriate space for the important new developments of meteorology the original classification was made too long ago. The International Catalogue has plenty of detail, but the numbers are very difficult to remember. The decimalized modification of it is not easy to remember, and it is somewhat difficult to use on such important subjects as winds, and effects of the weather.

Therefore, I have tried to make a classification with fewer divisions, especially in those parts of the subject where single papers (e. g. winds) usually cover several of the more refined divisions of classifications now in use. Subheadings can be made to suit individual requirements of those who may use this system. The order is in most respects the same as that shown in the outline on page 559 of the December, 1918, REVIEW. This classification is now in use in handling current material for the MONTHLY WEATHER REVIEW.

[1] Mo. Wea. Rev., 1915, 43: 362-364; review, Science, Feb. 11, 1916, p. 216.

GENERAL CLASSIFICATION OF METEOROLOGICAL LITERATURE.

00 General.

- 01 History. Biography.
- 02 Bibliographies, general treatises, textbooks, glossaries.
- 03 Periodicals. Reports of societies, etc.
- 04 Miscellaneous addresses, articles, and notes.
- 05 Teaching and research.

10 Observation.

- 11 Methods of observation. Work of observatories and weather services.
- 12 Kite and balloon stations and methods.
- 13 Radiation and temperature measurement.
- 14 Pressure measurement.
- 15 Wind and cloud movement observation.
- 16 Moisture measurement.
- 17 Meteorographs. Miscellaneous.
- 18 Tables for reductions.
- 19 Applications of mathematics.

20 Air.

- 21 Composition and extent of the atmosphere.
- 22 Thermodynamics of air.
- 23 Miscellaneous properties of air as a gas.
- 24 Acoustics.
- 25 Optics.
- 26 Atmospheric electricity.
- 27 Lightning.
- 28 Aurora. Magnetic storms.

30 Temperature.

- 31 Solar radiation.
- 32 Atmospheric scattering, absorption, and radiation.
- 33 Land-surface absorption, radiation, and temperature.
- 34 Water-surface absorption, radiation, and temperature.
- 35 Effect of surface on air temperature.
- 36 Vertical distribution of temperature.
- 37 Geographical distribution of temperature.

40 Pressure.

- 41 Vertical decrease of pressure and density. Hypsometry.
- 42 Pressure reduction to stated levels, for map making.
- 43 Pressure changes.
- 44 Wind pressure.
- 45 Geographical distribution of pressure.

50 Wind.

- 51 Convectional circulation. Local winds due directly to heating or cooling.
- 52 Vertical convectional currents in the free air.
- 53 Gradient (frictionless) wind. Actual wind.
- 54 Influence of the earth's surface on wind velocity and direction; turbulence.
- 55 Over- and under-running of winds. Wind billows.
- 56 General circulation of the atmosphere.

60 Moisture.

- 61 Evaporation. Humidity.
- 62 Dew and frost.
- 63 Condensation nuclei.
- 64 Fog. Fog ice deposits.
- 65 Cloud forms and their genesis.
- 66 Precipitation in general: causes, fluctuations, distribution.
- 67 Snow, sleet, rain, hail: characteristics, causes, and distribution of each.

70 Weather.

- 71 Weather abnormalities: changes in "grand centers of action."
- 72 Tropical cyclones.
- 73 Extra-tropical migratory cyclones and anticyclones considered as units: origin and maintenance, general characteristics, movement and paths.
- 74 Distribution of meteorological elements about and in cyclones and anticyclones.
- 75 Local storms: thunderstorms, squalls, tornadoes, and waterspouts.

80 **Application of meteorology.**

81 Weather forecasting: basis, (.1) Local, (.2) Collected observations.
82 Agricultural meteorology. Climate and crops. Phenology. Ecology.
83 Hydrology.
84 Manufacturing and business aspects of the weather.
85 Land transportation and the weather.
86 Marine meteorology. Oceanography.
87 Aeronautical meteorology.
88 Military meteorology.
89 Physiological effects of weather and climate on man.

90 **Climatology.**

91 General climatology: the climatic elements; climate in relation to latitude, surface covering, altitude, and exposure.
92 Climatography: climates of the world and their effects on the people. [Divided geographically by continents or natural regions.]
93 Changes of climate in historical and geological time.

BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Aitken, John.
Ground-ice. diagr. 27½ cm. (Reprinted from Journal of the Scottish meteorological society. 3d ser. vol. 18, no. 35. 1918. p. 13–18.)

Ångström, Anders.
Determination of the constants of pyrgeometers. Stockholm. 1918. cover-title, 16 p. 3 tables. diagrs. 22 cm. (Arkiv för matematik, astronomi och fysik . . . Band 13. No. 8. Meddelande från Uppsala universitets fysiska institution.)
On the radiation and temperature of snow and the convection of the air at its surface. Observations at Abisko in January 1916. Stockholm. 1918. cover-title, 18 p. tables. 22 cm. (Arkiv för matematik, astronomi och fysik . . . Band 13. No. 21.) Literature, p. 17–18.

Arrhenius, Svante [August].
The destinies of the stars: authorized tr. from the Swedish by J. E. Fries. New York [etc.] 1918. xvii, 256 p. plates. (part. fold.) 19½ cm. [Chapter 3.—The climatic importance of water vapour. 4.—Atmosphere and physics of the stellar bodies. 5.—The chemistry of the atmosphere.]

Batavia. Magnetisch en meteorologisch observatorium.
. . . Observations made at secondary stations in Netherlands East-India . . . Vol. 4–5. (1914–1915.) Batavia. 1917–1918. 2v. tables. 37 cm.
Observations made at the Royal magnetical and meteorological observatory at Batavia . . . Vol. 37, 1914 . . . Batavia. 1918. xxvi, 116 p. charts. tables. 36½ cm.

Chamber of commerce of the United States of America.
Relation of weather and business in regard to rainfall. Washington. 1919. 12 p. charts. 27½ cm.

Harvard travellers club.
Handbook of travel. Cambridge, Mass. 1917. 3 p. l., 544 p. plate. illus. tables. diagrs. 18 cm. [Meteorological observations, by R. DeC. Ward, p. [451]–472.]

Harvey, R[odney] B[eecher].
Hardening process in plants and developments from frost injury. Washington. 1918. plates. charts. tables. 26 cm. (Reprinted from Journal of agricultural research. Vol. 15, No. 2, p. 83–111.) Literature cited, p. 108–111.

Leverett, Frank.
Surface geology and agricultural conditions of Michigan; with a chapter on climate by C. F. Schneider. Lansing, Mich. 1917. 223 p. 23½ cm. (Michigan geological and biological survey. Publication 25. Geological series 21. Published as part of the Annual report of the Board of geological survey for 1917.)

Lourenço Marques. Observatório Campos Rodrigues.
Relatório. Ano de 1917. Volume 9. Lourenço Marques. 1918. 102 p. incl. tables. 38½ cm. At head of title: Provincia de Moçambique. Serviços de Marinha.

Lundblad, Ragnar.
A theory of the pyrgeometer of Ångström. Stockholm. 1918. cover-title, 10 p. 22 cm. (Arkiv för matematik, astronomi och fysik . . . Band 13. No. 7. Meddelande från Uppsala universitets fysiska institution.)

McEwen, George F[rancis].
Oceanic circulation and its bearing upon attempts to make seasonal weather forecasts. A sketch of observational methods and explanations. 20 p. 23½ cm. (Bulletin of the Scripps institution for biological research of the University of California. No. 7. [La Jolla, Cal.] 1918.) Bibliography, p. 19–20. [Largely historical.]

Maryland. Geological survey.
The geography of Maryland, by W. B. Clark. Baltimore. 1918. 5 p. l., [41]–167 [4] p. illus. maps. diagrs. 25½ cm. (Special publication, volume 10, part 1.) [Climate, p. 99–101.]

Mysore. Meteorological dept.
Report on rainfall registration in Mysore for 1917 . . . Bangalore. 1918. 1 p. l., xvii, 53 p. charts (part. fold.). tables. 31½ cm.

Salter, Carle.
The relation of rainfall to configuration. [London] 1918. cover-title, 37 p. charts (part. fold.). tables. 22 cm. At head of title: The institution of water engineers. [cf. pp. 33–41, M. W. R., Jan., 1919.]

Seeley, D[ewey] A[lsdorf].
The length of the growing season in Michigan. charts. tables. 23 cm. (Reprinted from the 20th Report of the Michigan academy of science [Lansing, Mich.] 1918. p. [223]–232.)

Shaw, [William] Napier.
Memorandum on atmospheric visibility. [London] 1918. 16 p. charts. 22½ cm. (Published for the Naval meteorological service, Hydrographical dept., Admiralty.) [Abstr. to be published in Feb. Review.]

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American journal of science. New Haven. v. 47. February, 1919.
Winchell, A. N., & Miller, E. R. Further notes on the dustfall of March 9, 1918. pp. 133–134. [cf. M. W. R., Nov., 1918.]
Aviation. New York. v. 6. February 15, 1919.
Tucker, Frank T. Winds and the transatlantic flight. p. 85.
Franklin institute. Journal. Philadelphia. v. 187. February, 1919.
Shelton, F. H. Windmills, picturesque and historic. p. 171–188.
Journal of geography. New York. v. 18. February, 1919.
Palmer, Andrew H. Water power in California. p. 41–53.
London, Edinburgh, and Dublin philosophical magazine. London. v. 37. January 1919.
Jeffreys, Harold. On travelling atmospheric disturbances. p. 3–8.
McLeod, A. R. On the lags of thermometers with spherical and cylindrical bulbs in a medium whose temperature is changing at a constant rate. p. 134–144.
Nature. London. v. 102. January 16, 1919.
Shaw, Napier. Climograph charts. p. 383.
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Physico-mathematical society of Japan. Proceedings. 3rd ser. v. 1. January, 1919.
Aichi, Keiichi. On the new method of reduction of observations of underground temperatures. p. 2-7.

Science. New York. v. 49. 1919.
Humphreys, W[illiam] J[ackson]. Some recent contributions to the physics of the air. p. 155-163; 182-188. (Feb. 14, 21.) [Cf. M. W. R., Dec., 1918.]

Scientific American supplement. New York. v. 87. 1919.
Cloud, W. S. A South Carolina meteor. p. 87. (Feb. 8.) [Repr. from Monthly Weather Review. Discusses meteorological features]
Thomas, J. S. G. Hot wire anemometry, its principles and applications. p. 106-107. (Feb. 15.) [Cf. p. 21 of Jan., 1919, M. W. R.]
Jakl, Vincent E. Notes on kite flying for meteorological observations. p. 110-112. (Feb. 15.) [Repr. from Monthly Weather Review, suppl. 13.]

Scottish meteorological society. Journal. 3rd ser. v. 17. 1917.
Douglas, C. K. M. The lapse-line and its relation to cloud formation. p. 133-147.
Fairgrieve, H. McCallum. The use of the climograph as a test for weather. p. 148-155.
Mitchell, A. Crichton. On the diurnal incidence of maximum and minimum temperatures at Eskdalemuir. p. 156-165.
Smellie, James, *and* **Watt, Andrew.** On a curious case of "ground ice." p. 166-173.

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Douglas, C. K. M. The upper air; some impressions gained by flying. p. 3-12.
Aitken, John. Ground ice. p. 13-18.
Mossman, R. C. The climate and meteorology of antarctic and subantarctic regions. p. 18-29.
Franklin, T. Bedford. Note on the fluctuations of mean sea-level in relation to variations in barometric pressure. p. 30-31.

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Hazard, D. L. The relation between seismic and magnetic disturbance. p. 117-124.
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Morgan, P. G. The New Zealand earthquake of August 6, 1917. p. 127-128.
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Hubert, Henri. Sur la superposition des courants aériens au-dessus de la presqu'île du Cap Vert (Sénégal). p. 99-102. (Jan. 13.)

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Mathias, E. La pluie en France. Calcul des anomalies et du coefficient d'altitude. p. 239-242. (27 jan.) [See p. 41, M. W. R., Jan., 1919.]

Aérophile. Paris. 26 année. 1918.
Lainé, André. Données élémentaires sur le plafond d'un avion. p. 264-265. (1-15 sept.) [The "ceiling" (*plafond*) of an aeroplane is the highest level it is able to attain.]
Frantzen, Lucien. Cartes de l'air. p. 335-337. (1-15 nov.)

Nature (La). Paris. 47 année. 1919.
Boyer, Jacques. Un thermomètre pour aveugles. p. 424. (11 Jan.) [Cf. Sci. Am., Jan. 25, 1919, p. 80.]
B., A. La canonnade et la pluie. p. 227. (25 jan.)

Beiträge zur Geophysik. Leipzig. 14. Band. 4. Heft. 1918.
Egerváry, Eugen v. Über die seismischen Trajektorien und über das Bertrandsche Problem in der Seismologie. p. 284-299.
Harboe, E. G. Die Bestimmung der Lage des Zentrums eines Fernbebens vermittelst der Pilgrimschen Laufzeittabellen. p. 300-317.
Friedlaender, Immanuel. Über die Nachbebenstösse des Erdbebens vom 13. Januar 1915 in Avezzano. p. 318-326.

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WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

Before examining in detail the weather of the current month, let us consider for a moment the general average weather conditions for January in the Northern Hemisphere. In that month pressure is high over the middle latitudes of the continents and low in the Arctic region and the northern portions of the Atlantic and Pacific Oceans. Pressure is highest over east-central Asia and lowest in the neighborhood of Iceland and also in the Gulf of Alaska. In the higher latitudes—say, to the northward of latitude 40° N., the prevailing winds are westerly, subject, of course to such variation as may be introduced by the current pressure distribution.

Current-pressure distribution.—Telegraphic and mail reports available at this writing show clearly that pressure in the middle western latitudes of the United States was considerably above the normal, and that immediately to the north, as in Canada and Alaska, pressure was for the most part below the normal.

The pressure of the two Pacific stations, Honolulu and Midway was generally above the normal. In this connection it is interesting to note that beginning in December, 1918, the uniformly low pressure which had prevailed at Honolulu since December, 1917, gradually merged into a type of moderately high pressure and that there was a still further increase in pressure at that station during the current month. Vessel reports from the North Pacific afford little definite information except as to the absence of gales. It may well be that such absence, especially in the Gulf of Alaska, is apparent rather than real, since it is known from reports of shore stations that there was a period of at least a week with fresh gales off the Washington and Oregon coasts and probably thence northward.

For the Atlantic area it is impossible to generalize freely, but there seem to have been the usual number of storms in the steamer lanes and during the last decade of the month to the southward, as indicated by reports from Bermuda and the Azores. In the first and second decades of the month pressure over middle latitudes in the Atlantic appears to have been above normal.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

Only incomplete vessel weather reports are available from the North Pacific Ocean at this writing. It appears, however, from those at hand that the month was almost entirely free from severe storms. Of a total of some 330 observations thus far received from ships on trans-Pacific routes, only 35 show winds of a force of 7 or greater. These are divided as follows: 17 of force 7, 10 of force 8, 8 of force 9. No winds exceeding force 9 have been reported. Twenty-one vessels reported no gales or storms. The quiet conditions indicated are such as would be inferred from the pressure distribution shown by daily observations at the several island stations of the bureau, viz, Dutch Harbor, Midway Island, and Honolulu. This pressure distribution is discussed elsewhere.

NORTH AMERICA.

By EDWARD H. BOWIE, Supervising Forecaster.

[Dated: Weather Bureau, Washington, Feb. 18, 1919.]

The meteorological conditions during January were in a marked degree like those of the month immediately preceding, and markedly unlike those of January, 1918. During the current month the temperature was above the normal over nearly all parts of the United States; there were no widespread cold waves, except for the one at the beginning of the month; there were no disturbances attended by heavy and widespread falls of snow or sleet; and there were no destructive gales in the interior, and few on the coasts. Similar meteorological conditions prevailed during December, 1918. It will be recalled that December, 1917, and January, 1918, were months of great and prolonged cold waves, unusual falls of snow and sleet, and severe wind storms,[1] and hence these two months stand out in marked contrast with the two just passed.

It will be of interest therefore to set forth in some detail the apparent reasons why the two months of the current winter were so dissimilar to the same months of the preceding winter. First, it may be said that meteorologists are not agreed as to the primary causes that bring about such striking contrasts in atmospheric phenomena such as occurred in December, 1918, and January, 1919, and the corresponding months of the winter of 1917–18. That profound modifications of the general or primary circulation of the atmosphere are involved there seems no doubt, but what brings these about it is not possible to say. These modifications in the general circulation are unquestionably shown in the general distribution of air pressure over the Alaskan area and the Pacific Ocean, and since the types of LOWS and HIGHS that cross the United States seem to be predetermined by the pressure distribution within these areas, it follows that any abnormalities over these areas will be reflected in the atmospheric conditions in the United States.

Normally the pressure is low during the winter months over Alaska and the Aleutian Islands and high over the middle latitudes of the Pacific Ocean, but there are periods when this pressure distribution is intensified and other times when there is a complete reversal of this distribution. During such times marked departures from normal atmospheric phenomena of the United States occur. The connection between the pressure distribution prevailing over the Pacific Ocean and Alaska and the weather of the United States has been set forth in Supplement No. 4, M. W. R., *Anticyclones of the United States.* Particularly interesting in this connection will be found the accompanying graphs of pressure for December, 1918, and January, 1919, and the corresponding months of the winter of 1917–1918. (Charts E. H. B. XI and XII.) Attention is drawn to the striking dissimilarity in the departures from the normal pressures at the several stations. It will be noted that during the two months just passed the pressure was consistently below the normal in the Alaskan area, and above the normal over the middle latitudes of the Pacific Ocean, as shown by the daily observations at Honolulu and Midway Island, while during December,

[1] Cf. P. C. Day, "The Cold Winter of 1917-18" Mo. Wea. Rev., Dec., 1918, 46: 570-580, 4 figs, 24 charts.

1917, and January, 1918, opposite departures were the rule. It will be noted further that during the past two months there was a general deficit in air weight over the Aleutian Islands and Alaska, and it followed therefore that few pronounced areas of high barometer formed in that region and moved southeastward over the United States. Consequently, the temperature was generally above the normal, cold waves were infrequent, and heavy falls of snow and sleet confined to small areas. During the corresponding months in the winter of 1917-1918, there was a marked excess of air weight over Alaska and the Aleutian Islands, and it followed that there was a more or less constant drainage of cold air from these regions southeastward over the United States. The result was a succession of widespread cold waves, frequent and widespread falls of snow and sleet, and a general intensification of winter weather conditions in the United States. Attention is invited to a consideration of the charts of tracks of high and low pressure areas across the United States, published in this number of the REVIEW and also those of December, 1918, and December, 1917, and January, 1918. These will show the marked dissimiliarity in the types of cyclones and anticyclones during these months.[2]

During the current month nearly all LOWS crossing the United States were of the North Pacific and Alberta types; they passed rapidly eastward along the northern border. The only exceptions to this statement were two LOWS that formed over southern Texas and another that passed inland from the Oregon coast, moved thence southeastward to the mouth of the Rio Grande and from that region northeastward to the Canadian Maritime Provinces. In respect to HIGHS, none appeared over the western Canadian Provinces; four passed inland from the Pacific Ocean and eight made their appearance north of the Great Lakes or in the region of Manitoba, and of these one passed southward over the Middle West and the others passed eastward and southeastward to the Atlantic coast.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

On account of war conditions the number of weather reports from the ocean was greatly reduced during the past year and the data available for the usual monthly discussion that should have been prepared for January, 1918, are too incomplete to justify an attempt at the present time to summarize. Instead, a short review of the weather for the current month has been prepared from the data so far received. It is necessarily incomplete, particularly for the latter part of the month, for which few reports are yet available.

On the 1st and 2d two vessels in the region between latitude 47° and 50° and longitude 30° and 33°, experienced strong northwesterly gales, with accompanying barometric readings of 29.72 inches and 30.07 inches, respectively, no other gale reports being received for these dates.

On the 3d the general conditions were very much the same as on the two previous days, except that there was a slight fall in the barometer readings. On the 4th and 5th moderate gales were recorded by a few vessels in widely scattered parts of the ocean.

According to the reports received the heaviest weather of the month occurred on the 6th (Chart IX); the center of the principal disturbance on that date was apparently about 10° west of the Irish coast, and northwesterly gales of from 60 to 90 miles an hour, with a minimum barometric reading of 28.67 inches, accompanied by "hail" and snow, were encountered by a number of vessels at short distances south of the center, the storm apparently covering the greater part of the steamer lanes, as far west as the 40th meridian. On the same day moderate gales, with rain and snow, were also reported in the region between latitude 37° to 41°, and longitude 63° to 66°. On the 7th the center of the European disturbance was apparently off the southwest coast of Ireland, which was swept by gales of over 60 miles an hour, the lowest barometric reading being 28.63 inches. The storm area had contracted considerably since the day before, as no high winds were reported west of the 27th meridian.

On the 8th, 9th, and 10th no well-defined area of low pressure could be determined, although storm reports were received from vessels in all parts of the steamer lanes.

On the 11th two vessels located near latitude 55°, longitude 42°, and latitude 49° and longitude 38°, respectively, encountered westerly gales of over 60 miles an hour, with "hail" and snow, and a barometer reading of 28.98 inches at the first position, probably not far from the center of the LOW. At the same time moderate westerly gales occurred in the region between Nova Scotia and the 40th parallel, while snow was reported at Halifax.

On the 12th (Chart IX) the entire territory between the 40th and 53d parallels, and the 30th meridian and the American coast, was swept by westerly and southwesterly gales of from 40 to 75 miles an hour, accompanied by snow. The center of this disturbance had apparently moved about 7 degrees eastward since the previous day, and was now near latitude 52, longitude 35. The conditions on the 13th and 14th and 15th, were similar to those of the 12th, and the LOW was evidently drifting slowly eastward, as on the 15th it was somewhere between the 25th meridan and the coast of Scotland.

On the 16th and 17th moderate gales were reported over different sections of the ocean, particularly between the 40th meridian and the Azores.

From the 18th to 21st, heavy weather still prevailed over the greater part of the steamer lanes, and on the 19th and 20th the storm area extended unusually far south, as winds of over 50 miles an hour were recorded in the region between the 35th and 40th parallels and the 52d and 56th meridians.

On the 22d a vessel near latitude 58, longitude 22, encountered southerly winds of about 50 miles an hour. No reports were received for the 23d, and on the 24th (Chart IX) there was apparently a well developed LOW central near latitude 38, longitude 68; strong northerly gales swept the coast between Hatteras and the Virginia Capes, and equally strong westerly and southerly winds were encountered over the southern and eastern quadrants of the storm area. No additional storms were reported until the 30th when one vessel near latitude 38, longitude 71, encountered a northwesterly gale of about 65 miles an hour, and a second report was received from near latitude 48, longitude 33, indicating westerly winds of the same force.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

BRITISH ISLES, JANUARY 1919.

With many cyclones passing over the British Isles, January precipitation was 155 per cent of normal in England and Wales, 122 in Ireland, and 94 in Scotland. Heavy snowstorms occurred January 3-4, and 27.—Sym. Met. Mag., Feb. 1919.

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[2] Cf. also P. C. Day, ibid.

NEW ZEALAND WEATHER FOR PAST YEAR.

By ALFRED A. WINSLOW, American Consul-General.

[Dated: Auckland, New Zealand, Jan. 6, 1919.]

The rainfall at Auckland was about 55 inches for 1918, of which less than 5 inches fell during November and December, as compared with 74½ inches for 1917 and 67½ for 1916; while the winter was exceptionally cold, and the present spring and summer to date have been the coolest for many years, and frosts and snowfalls have been quite common in different parts of the islands until recently, to the detriment of grain and fruit crops, young lambs and shorn sheep, and country life in general.

DETAILS OF THE WEATHER IN THE UNITED STATES, JANUARY, 1919.

CYCLONES AND ANTICYCLONES.

By A. J. HENRY.

The weather in the United States may be summarized in a single paragraph as follows: The normal winter LOW of Alaska was moderately well developed and extended at times southeastward, overspreading British Columbia and the Canadian northwest. This development in conjunction with a general increase in pressure over middle latitudes, most pronounced in the mountain regions of Colorado, Utah, Idaho, and Wyoming, had a tendency to increase the gradient for south to west winds along the northern boundary of the United States. It also appears that associated with this pressure distribution there was a preponderance of LOWS of the north Pacific and Alberta types, moving rapidly eastward along the northern border of the United States. The following-named exceptions may be noted: Two LOWS, which first appeared over southern Texas, moved thence east-northeast, and a third LOW passed inland over Oregon, moved thence southeastward to the mouth of the Rio Grande, and thence northeastward to the Canadian Maritime Provinces. In respect to HIGHS, four passed inland from the Pacific and eight first appeared north of the Great Lakes or in the Province of Manitoba, and of these one passed southward over the Middle West, the remainder passing eastward and southeastward to the Atlantic. (See Charts II and III.)

The leading feature of the month was, of course, the mild temperature experienced, especially in some portions of the Northwest where the month as a whole was among the warmest of record and in striking contrast to that of January, 1918.

THE WEATHER ELEMENTS.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Mar. 1, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for January, 1919, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

The pressure distribution for the month was marked by two unusual features—first, the almost constantly maintained HIGH over the Plateau region; and, second, the equal persistence of shallow LOWS along the northern border. As a result the average for the month was well above the normal over the entire region from the Rocky Mountains westward, and from the central Plains eastward to near the Atlantic coast, the center of the highest pressure being maintained in the Middle Plateau.

Over the whole of Canada, as far as observations indicate, the pressure was low throughout the month, the negative departures being quite large in the Northwest Provinces. In the United States pressure averaged below the normal over all northern districts from the Missouri Valley eastward, and along the Atlantic coast to southern Florida.

The general tendency of high pressure toward the south favored winds with strong southerly components over most central and northern districts, while along the southern borders there was a pronounced tendency to winds with northerly components. Over the Middle Plateau the winds maintained the distinctive type present in anticyclones, and were mainly outward from the center of highest pressure. The effects of these winds upon the temperature is clearly apparent on Chart No. IV, departure of the mean temperature from the normal.

TEMPERATURE.

At the beginning of the month abnormally warm weather prevailed east of the Mississippi River, but temperatures were about 20° below the normal in practically all western districts, with readings below zero as far south as the Texas Panhandle, and also over the Rocky Mountain and Plateau regions. This western cold wave overspread eastern localities during the next few days, and the line of freezing temperature extended well into Florida by the morning of the 4th. Warmer weather followed, although the temperature continued somewhat below the normal until the latter part of the first decade in most sections.

During the second decade, moderate temperatures prevailed in the northern and central districts east of the Rocky Mountains, but temperatures below the seasonal average continued in the central and southern Rocky Mountain and Plateau districts, and in other portions of the South. The third decade was marked throughout by abnormally warm weather in the North, and by moderate temperature in most other districts, although in the southern Plateau and Rocky Mountain regions and the Gulf States temperature continued generally below the normal until near the end of the month. During the closing days temperatures were near the normal almost everywhere throughout the country.

While January as a whole was unusually warm over all central and northern districts, being one of the warmest of record in portions of the far north, and remarkably free from even moderate cold periods, nevertheless over small areas in the southern Rocky Mountain and Plateau regions the month as a whole was unusually cold. This was particularly noticeable in southeastern Utah and the adjacent portions of Arizona, New Mexico, and Colorado, where the prevailing clear weather and general snow cover left over from the heavy falls of the early part of the winter favored intense night radiation. As a result minimum temperatures were unusually low throughout the entire month, and the average temperatures were locally among the lowest of record. (See note in a later REVIEW).

PRECIPITATION.

The month opened with snow in the northern and rain in nearly all central and southern districts east of the Mississippi River, and also in the west Gulf States,

the falls being heavy in Tennessee and portions of the Ohio Valley. During the next few days rain or snow continued in eastern districts, with heavy rainfalls in portions of the Atlantic coast States. During the remainder of the first decade unsettled weather prevailed in many eastern sections, with frequent precipitation, but over the middle and western districts practically no precipitation occurred throughout the decade. The first half of the second decade was marked by an unusual absence of precipitation in practically all portions of the country, but toward the end general rains prevailed in the Gulf and Atlantic coast States, with some heavy falls in Texas, though in most other portions of the country the weather continued fair.

During the first few days of the third decade there was an unusual absence of precipitation of any character, save over the extreme eastern and western districts where rain or snow fell in some sections. With the exception of local precipitation over a few limited areas, the remainder of the decade was almost continuously free of clouds or precipitation.

The month as a whole had unusually light precipitation in nearly all districts; in fact, the monthly amounts were everywhere less than normal, save over small areas in the southern States and along the north Pacific coast. Many localities in the Middle West, and generally the lower elevations of the Mountain and Plateau regions received little or no precipitation of any character during the entire month.

SNOWFALL.

The month opened with a considerable portion of the country under a moderate cover of snow left over from the December falls. The heavy snows of the early winter in the southwest had remained unmelted, due to continued cold, and at the beginning of January the western portions of Kansas, Oklahoma, and Texas and the higher elevations of New Mexico, Arizona, southeastern Utah, and southern Colorado had a covering far deeper than usual so early in the season. Over other portions of the country where a covering existed the amounts were generally light and much below the normal. This was particularly true for portions of the Lakes region, New England, and the mountains of the Pacific States. In California the snow stored in the mountains at the beginning of the month was only a small per cent of that usual for the period of the year.

The snowfall for January was nearly everywhere remarkably light, and under the influence of much sunshine and generally moderate temperatures the snow-covered area rapidly diminished, save for occasional increases over small areas. By the close of the month the snow cover had disappeared, except for small areas in the more northern districts and at the higher elevations in the western mountains.

The snowfall stored in the mountains at the end of the month was nearly everywhere deficient as compared with the usual amount, and the outlook in the districts where the water supply is usually dependent upon the snowfall was generally discouraging—in some sections the poorest known. In some of the more northern districts, particularly Idaho, there was a moderate accumulation of snow. In the Lakes region the absence of any material snow cover was seriously hindering logging operations, the success of which depends much upon a good covering of snow as an aid in transportation.

RELATIVE HUMIDITY.

For the month as a whole the relative humidity was higher than usual for January throughout the central and southern portions of the Rocky Mountain and Great Plains regions and in the west Gulf States. Elsewhere it was generally below the normal, and over local areas negative departures were unusually large, notably in portions of the Plateau region and in central and southern California.

Average accumulated departures for January, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	° F.	° F.	° F.	Ins.	Ins.	Ins.	0-10.		P. c.	
New England	29.2	+ 5.1	+ 5.1	3.24	−2.5	−2.5	6.6	+0.6	77	+ 1
Middle Atlantic	36.4	+ 4.8	+ 4.8	3.14	−0.1	−0.1	5.3	−0.7	73	− 3
South Atlantic	47.8	+ 2.6	+ 2.6	3.52	−0.3	−0.3	4.9	−0.4	74	− 3
Florida Peninsula	64.3	− 1.1	− 1.1	1.42	−1.0	−1.0	5.7	+0.9	79	− 3
East Gulf	46.9	− 0.4	− 0.4	5.68	+0.7	+0.7	5.2	−0.5	75	− 2
West Gulf	46.4	+ 0.3	+ 0.3	3.08	+0.1	+0.1	5.4	0.0	77	+ 2
Ohio Valley and Tennessee	36.8	+ 3.8	+ 3.8	2.66	−1.2	−1.2	5.4	−1.1	74	− 3
Lower Lakes	30.4	+ 6.1	+ 6.1	1.19	−1.5	−1.5	6.3	−1.2	76	− 4
Upper Lakes	25.8	+ 7.5	+ 7.5	0.83	−1.3	−1.3	6.8	−0.2	84	+ 2
North Dakota	19.7	+15.7	+15.7	0.15	−0.4	−0.4	5.1	+0.1	80	− 1
Upper Mississippi Valley	29.2	+ 7.7	+ 7.7	0.25	−1.5	−1.5	4.7	+0.9	79	− 1
Missouri Valley	31.7	+10.7	+10.7	0.11	−0.9	−0.9	3.6	−1.5	75	− 2
Northern slope	29.5	+10.5	+10.5	0.25	−0.6	−0.6	4.3	−0.9	65	− 8
Middle slope	33.4	+ 4.4	+ 4.4	0.09	−0.6	−0.6	2.5	−1.8	72	+ 4
Southern slope	38.2	− 3.3	− 3.3	0.89	+0.2	+0.2	3.9	−0.6	72	+ 8
Southern Plateau	39.2	− 1.6	− 1.6	0.13	−0.6	−0.6	2.1	−1.4	45	− 7
Middle Plateau	28.1	− 0.4	− 0.4	0.16	−0.9	−0.9	3.4	−2.0	65	− 7
Northern Plateau	32.4	+ 3.6	+ 3.6	1.19	−0.4	−0.4	5.6	−1.3	71	− 9
North Pacific	42.4	+ 2.4	+ 2.4	8.72	+2.0	+2.0	7.8	+0.2	84	− 2
Middle Pacific	48.4	+ 1.1	+ 1.1	3.25	−1.5	−1.5	4.4	−1.5	75	− 6
South Pacific	54.6	+ 3.8	+ 3.8	0.87	−1.9	−1.9	3.0	−1.7	58	−13

Winds of 50 mis./hr. (22.4 m./sec.) or over, during January, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Block Island, R. I.	10	59	nw.	North Head, Wash.	11	50	s.
Do	11	56	nw.	Do	14	88	se.
Do	24	60	w.	Do	15	72	nw.
Buffalo, N. Y	1	64	sw.	Do	16	80	s.
Do	2	60	sw.	Do	17	84	s.
Do	8	60	sw.	Do	21	58	s.
Do	9	62	sw.	Do	22	70	s.
Do	10	78	sw.	Do	23	68	s.
Do	16	54	sw.	Do	25	64	s.
Do	17	60	sw.	Pensacola, Fla	16	60	s.
Do	30	52	sw.	Point Reyes Light, Cal.	19	64	s.
Burlington, Vt	1	60	s.	Do	24	50	nw.
Cheyenne, Wyo	3	50	w.	Do	31	80	nw.
Do	6	54	w.	Providence, R. I.	24	79	nw.
Do	17	58	w.	Do	31	54	nw.
Do	18	50	w.	Sandy Hook, N. J	1	50	s.
Do	24	51	w.	Do	9	53	nw.
Detroit, Mich	10	54	w.	Do	10	53	w.
Duluth, Minn	8	51	w.	Do	24	58	w.
Eastport, Me	24	52	e.	Seattle, Wash	23	52	sw.
Ellendale, N. Dak	16	52	nw.	Tatoosh Island, Wash	10	52	s.
Ludington, Mich	8	50	sw.	Do	12	52	sw.
Mount Tamalpais, Cal	19	62	s.	Do	13	54	s.
Nantucket, Mass	10	56	sw.	Do	14	91	s.
New York, N. Y	1	53	s.	Do	16	64	s.
Do	9	64	nw.	Do	17	72	s.
Do	10	62	nw.	Do	21	50	s.
Do	11	52	nw.	Do	22	54	e.
Do	19	51	nw.	Do	23	64	sw.
Do	24	84	nw.	Toledo, Ohio	10	52	w.

SPECIAL FORECASTS AND WARNINGS. WEATHER AND CROPS.

WEATHER WARNINGS.

By E. H. BOWIE, Supervising Forecaster.

WASHINGTON DISTRICT.

Cold wave and frost warnings.—On the morning of the 1st when the pressure was abnormally low over a wide belt extending from the Great Lakes southward to the Gulf of Mexico, cold-wave warnings were issued for the Upper Lakes Region, the Lower Ohio Valley, Tennessee, the East Gulf States, Northwestern Florida and Northwestern Georgia. Much colder weather followed over these areas during the succeeding 36 hours, freezing weather occurring during the night of the second as far south as the middle Gulf coast and northwestern Florida. On the evening of the 2d the display of cold-wave warnings was extended eastward over the Carolinas, eastern and southern Georgia and northern and central Florida, and a pronounced change to colder weather overspread these regions during the 3d and 4th, when freezing temperature and frost occurred as far south as central Florida. The cold weather continued in the South Atlantic and east Gulf States until the 12th, and during this period warnings of frosts were issued for these regions almost daily. After this date, the 12th, the weather became comparatively warm in the Southern States and no more warnings of cold waves or frosts were required for the Southern States. On the evening of the 10th it was announced that—

> The extraordinarily rapid movement of disturbances along the northern border continues. A storm passed eastward off the New England coast Thursday, the 9th, and another had advanced along the northern border and Friday night, the 10th, was over the St. Lawrence Valley. Another had appeared to the north of Montana and yet another off the North Pacific coast. The storm that passed off the coast Thursday was followed by decidedly colder weather during Thursday night in the Lower Lakes Region, the Middle Atlantic and New England States, warning of which was issued on the 9th. This change to colder weather was of short duration, however, and during Friday much warmer weather prevailed in the Ohio Valley, the region of the Great Lakes, and interior of the Middle Atlantic States. This change to warmer weather will be of short duration, however, *as a cold wave has already made it appearance to the north of the Great Lakes and will advance southward and eastward over the Great Lakes, the Upper Ohio Valley, and the Middle Atlantic and New England States within the next 36 hours.*

Warnings were issued accordingly and were fully verified, the coldest weather of the month occurring over much of these regions during the 11th and 12th. On the 24th cold wave warnings were issued for the New England States, New York, and northeastern Pennsylvania, and while a considerable fall in temperature followed during the 25th it was not of sufficient importance to justify the warnings.

Storm warnings.—On the morning of the 1st, when an intense storm was central over the Great Lakes southwest storm warnings were ordered for the Atlantic coast, but as this storm failed to maintain its intensity the warnings failed of verification except along the coast from the Virginia capes northward to Cape Cod, where winds of gale force occurred during the night of the 1st. On the evening of the 2d northeast storm warnings were displayed on the Atlantic coast between Cape Hatteras and Boston, when a storm of moderate intensity was central over South Carolina. This storm passed up the coast and increased decidedly in intensity, and the morning of the 3d the display of warnings was extended northward to Eastport, Me. Strong winds prevailed along the coast, but at no point did the velocity reach gale force. Warnings were displayed the afternoon of the 8th between New York City and Wilmington, N. C., at which time a disturbance was developing over the Florida Peninsula and at the same time a disturbance was passing eastward over the Great Lakes. On the morning of the 9th the warning was changed to "northwest" and continued between New York City and Cape Hatteras, and the area covered by warnings extended northward to Portland, Me. These disturbances apparently united off the New England coast during the 9th, and gales were general on the coast where warnings were displayed, during the afternoon and night of the 9th. On the 10th the warnings were continued but changed to "southwest" on the Atlantic coast from Delaware Breakwater northward to Eastport, Me., the expected strong winds to result from the eastward passage of a cyclone that was over Lake Superior the morning of the 10th. Heavy winds occurred during the night of the 10th and on the 11th north of Delaware Breakwater.

Storm warnings were again displayed on the 18th between Cape Hatteras and Eastport, when a disturbance of considerable intensity was over North Carolina and another was over Lake Erie; these disturbances passed northeastward without causing winds of gale force on the Atlantic coast. On the afternoon of the 23d storm warnings were displayed at and north of Cape Hatteras, and during the night of that date a disturbance of marked intensity developed off the New England coast; it was attended by shifting gales on the Middle Atlantic and New England coasts. The warnings were continued the morning of the 24th at and north of Delaware Breakwater, heavy westerly gales continuing through that day. A storm formed during the night of the 24th over the Gulf of Mexico, and on the afternoon of the 25th warnings were displayed on the East Gulf coast and on the Atlantic coast south of Cape Hatteras. This disturbance advanced rapidly northeastward and left the Atlantic coast near Cape Hatteras the morning of the 26th, without being attended by winds of storm force.

Warnings of heavy snowfalls.—No heavy snowfall warnings were required during the month in the Washington forecast district.

Northers, Panama Canal.—The following communication was received from the Chief Hydrographer of the Panama Canal:

> Referring to the cabled storm warning received the 4th instant, "Strong northerly winds indicated next 36 hours over western Carbibean Sea will probably prevail as far south as Colon," the following weather conditions prevailed at the Atlantic entrance of the Canal:
>
> Winds increased Sunday, January 5, to 18 miles an hour from the north, with a maximum velocity of 24 miles an hour from the north. Northeast winds prevailed on the 6th, with an average hourly velocity of 18 miles, and a maximum velocity of 27 miles an hour from the northeast. Higher wind velocities probably prevailed out at sea, and it is thought that the forecast for the western Caribbean Sea was verified.
>
> Windy and unsettled weather continued throughout the week ending January 13, culminating in a "near-norther" on January 12, with an average hourly wind velocity of 20 miles, and a maximum velocity of 32 miles from the north. Unusually heavy seas prevailed on the 11th and 12th, causing some damage to the breakwaters and washing away the small beacon light on Coco Solo Breakwater. The character and magnitude of the swell indicated the prevalence of much higher wind velocities out at sea.

RIVERS AND FLOODS, JANUARY, 1919.

By ALFRED J. HENRY, Meteorologist.

[Dated: Weather Bureau, Washington, Mar. 3, 1919.]

Rain, almost continuous from the 16th to the 24th, in Washington, Oregon, and northern California, caused floods in the streams of those States, and in some cases

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serious interruption to traffic, with the loss of bridges, roadbed, and timber rafts. In all other parts of the country, practically all of the floods were due to the general rainstorm which passed eastward from the 1st to the 3d. No severe floods occurred.

Warnings were issued generally well in advance of the flood crest for all rivers on which a warning service is maintained. The usual details and tabular matter follow:

Moderately heavy rains in the South Atlantic and east Gulf States from the 1st to 3d caused most of the streams to rise slightly above the flood stage. This rise had subsided by the 6th to 8th, except in the lower reaches of a few streams. The rivers rose again to near flood stage on the 27th to 29th. At a few places the rivers overflowed to a depth of 2 to 4 feet. These floods did considerable damage, but the main loss was due to the suspension of business.

The heavy rains of the 1st to 3d were quite general in the Ohio River watershed and caused sharp rises in the rivers; but the cold weather of the succeeding days checked the run-off, so that only moderate flood stages were reached on the main stream. Most of the tributaries were slightly above flood stage, but the Allegheny River reached the flood stage at Herrs Island Dam only.

The damage caused by these floods was confined largely to the Pittsburgh and Nashville districts.

Flood stage was not reached on the Mississippi River except at Arkansas City, Ark. The western tributaries below the Ohio River were in slight flood in the lower reaches during the first decade. The Atchafalaya and Sulphur Rivers were bank-full during the last week of the month.

The flood that was in progress in the Trinity River in Texas at the end of December had subsided by the 6th. A sharp rise to near flood stage occurred from the 17th to 20th and a second rise to slightly above flood stage occurred during the last week of the month. The Guadalupe River at Victoria, Tex., was 3.6 feet above flood stage on the 25th. Very little damage resulted from these high waters.

Excessive rains on the 16th and 17th in the Eel River watershed, California, caused a sharp rise in the stream. About 5,000 acres of land were overflowed and damaged by washing and being covered with drift.

Heavy rains beginning on the 15th and continuing for a week caused the Willamette River in Oregon and its tributaries to slightly exceed bankful stages during the latter part of the month.

The estimated losses by floods and by property saved by warnings are shown in the following table:

Estimated loss by flood, January, 1919.

River district.	Tangible property, bridges, etc.	Crops.	Live stock.	Suspension of business.	Value of warnings.
Richmond, Va.	$175			$19,720	$10,000
Raleigh, N. C.	5,000		$2,500	10,000	50,000
Columbia, S. C.	8,300	$4,275	4,800	2,300	65,800
Charleston, S. C.	500		400	20,000	35,000
Mobile, Ala.			1,250		22,500
Meridian, Miss.		500	1,000	2,000	2,000
Pittsburgh, Pa.	75,000				100,000
Cincinnati, Ohio.					50,000
Cairo, Ill.	500	2,000		1,000	51,000
Nashville, Tenn.	3,650	1,800	575	12,750	33,000
Eureka, Cal.	4,400		240	3,500	
Total.	97,575	8,575	10,765	71,270	419,300

TABLE I.—*Flood stages in the North Atlantic drainage during January, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
James:	*Feet.*			*Feet.*	
Buchanan, Va.	15	3	3	18.0	3
Columbia, Va.	18	3	5	29.0	3
Richmond, Va.	10	4	5	17.2	5
Roanoke:					
Randolph, Va.	21	4	5	24.9	4
Weldon, N. C.	30	4	7	40.8	6
Dan:					
Danville, Va.	8			7.9	4
Clarksville, Va.	12	5	5	12.8	5
Neuse:					
Neuse, N. C.	14	5	7	16.4	6
Do.	14			13.6	21
Do.	14			13.9	28
Smithfield, N. C.	14	6	8	15.4	6
Do.	14			12.2	22
Do.	14			13.8	28
Cape Fear:					
Elizabethtown, N. C.	22	5	7	26.5	6
Do.	22	28	29	24.1	29
Fayetteville, N. C.	35			34.4	4
Peedee:					
Cheraw, S. C.	27	4	6	32.8	4
Do.	27	27	28	31.0	27
Santee:					
Rimini, S. C.	12	(1)	16	18.6	[2] 29
Do.	12	19	(3)	17.0	31
Ferguson, S. C.	12	(1)	18	13.8	9-10
Do.	12	19	(3)	13.8	31
Catawba, S. C.	11	3	4	13.0	4
Do.	11	27	27	11.0	27
Wateree:					
Camden, S. C.	24	4	5	30.0	5
Do.	24	27	28	29.0	28
Congaree:					
Columbia, S. C.	15			14.0	4
Do.	15	27	27	15.8	27
Broad:					
Blairs, S. C.	15	4	4	15.8	4
Do.	15	27	27	16.2	27
Saluda:					
Pelzer, S. C.	7	3	3	7.4	3
Chappell, S. C.	14	4	5	14.2	5
Do.	14	26	28	15.9	27
Ocmulgee:					
Macon, Ga.	18			15.0	3
Abbeville, Ga.	11	(1)	3	14.8	[2] 29
Lumber City, Ga.	15	2	3	15.3	2

[1] Continued from December. [2] December. [3] Continued into February.

TABLE II.—*Flood stages in the East Gulf drainage during January, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Flint:	*Feet.*			*Feet.*	
Bainbridge, Ga.	25			23.5	1
Alabama:					
Selma, Ala.	35			34.3	29
Coosa:					
Gadsden, Ala.	22			19.7	28
Lock No. 4, Lincoln, Ala.	17	27	28	17.1	27
Etowah:					
Canton, Ga.	11			10.1	26
Tombigbee:					
Demopolis, Ala.	39	5	15	47.0	10
Black Warrior:					
Tuscaloosa, Ala.	46	4	4	47.0	4
Pascagoula:					
Merrill, Miss.	20			18.5	29
Pearl:					
Jackson, Miss.	20	4	19	24.3	11-12
Columbia, Miss.	18			17.5	6
West Pearl:					
Pearl River, La.	13	(1)	2	14.0	[2] 29
Do.	13	8	31	15.3	29

[1] Continued from preceding month. [2] December.

TABLE III.—*Flood stages in the Mississippi drainage (Ohio Basin) during January, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Ohio:	Feet.			Feet.	
Pittsburgh, Pa	22	3	3	22.8	3
Davis Island Dam, Pa	25	....	....	22.7	3
Lock No. 2, Coraopolis, Pa	26	....	....	24.0	3
Beaver Dam, Pa	30	3	3	32.4	3
Dam No. 13, near Wheeling	36	....	....	34.6	3
Marietta, Ohio	33	....	....	30.7	4
Parkersburg, W. Va	36	....	....	32.4	4
Point Pleasant, W. Va	40	3	5	45.0	4
Dam No. 26, Hogsett, W. Va	50	....	....	48.3	4
Dam No. 28, Huntingdon, W. Va	50	....	....	48.6	4
Dam No. 29, Normal, Ky	50	4	5	52.7	4
Portsmouth, Ohio	50	4	5	51.5	4
Maysville, Ky	50	5	5	50.0	5
Cincinnati, Ohio	50	5	7	52.0	6
Dam No. 37, Fernbank, Ohio	50	....	....	47.5	6
Dam No. 39, Florence, Ind	50	....	....	43.3	6
Madison, Ind	46	....	....	44.3	6
Louisville, Ky	28	....	....	27.6	7
Cloverport, Ky	40	6	10	43.4	8
Henderson, Ky	33	5	13	39.0	9–10
Evansville, Ind	35	5	13	40.9	9
Mt. Vernon, Ind	35	6	14	40.0	10
Shawneetown, Ill	35	5	14	40.6	11
Paducah, Ky	43	....	....	40.5	12
Cairo, Ill	45	....	....	41.3	13
Allegheny:					
Herrs Island Dam, Pa	22	2	3	23.4	2
Monongahela:					
Fairmont, W. Va	25	2	2	30.3	2
Greensboro, Pa	20	2	3	31.4	2
Lock No. 4, Pa	31	2	3	40.0	2
Cheat:					
Rowlesburg, W. Va	12	....	....	11.2	2
Little Kanawha:					
Glenville, W. Va	22	2	2	27.4	2
Creston, W. Va	20	2	2	24.6	2
Muskingun:					
Marietta, Ohio	32	4	4	32.2	4
Tuscarawas:					
Norris Point, Ohio	8	....	....	7.8	3
Scioto:					
Circleville, Ohio	7	2	3	8.4	3
Kanawha:					
Kanawha Falls, W. Va	25	....	....	24.2	2
Charleston, W. Va	30	2	3	35.6	2
Greenbrier:					
Renick, W. Va	17	....	....	15.4	2
Elk:					
Clay, W. Va	18	2	2	22.7	2
Tug Fork of Big Sandy:					
Williamson, W. Va	26	....	....	24.6	2
Big Sandy:					
Pikeville, Ky	35	....	....	32.0	2
Licking:					
Farmers, Ky	25	2	2	25.5	2
Falmouth, Ky	28	....	....	26.7	2
South Fork of Licking:					
Cynthiana, Ky	20	....	....	18.3	2
Kentucky:					
Jackson, Ky	24	2	2	26.5	2
Beattyville, Ky	30	....	....	29.5	2–3
High Bridge, Ky	30	2	2	34.4	2
Frankfort, Ky	31	2	3	33.0	3
Green:					
Lock No. 6, Brownsville, Ky	30	2	6	45.0	4
Lock No. 4, Woodbury, Ky	33	2	9	48.2	5
Lock No. 2, Rumsey, Ky	34	5	15	40.5	11
Wabash:					
Mt. Carmel, Ill	15	(1)	7	21.5	[2] 30
White:					
Decker, Ind	18	(1)	1	19.8	[2] 29–30
Cumberland:					
Williamsburg, Ky	22	....	....	20.7	3
Burnside, Ky	50	2	3	58.0	2
Celina, Tenn	45	3	6	47.4	5
Carthage, Tenn	40	3	8	46.7	4
Nashville, Tenn	40	2	11	44.9	7–8
Lock A, Fox Bluff, Tenn	43	4	4	43.9	4
Clarksville, Tenn	46	3	11	48.6	4
Lock D, Dover, Tenn	49	5	12	50.8	9–11
French Broad:					
Penrose, N. C	13	....	....	12.2	3
Asheville, N. C	4	3	3	4.0	3
Dandridge, Tenn	12	....	....	11.0	3
Big Pigeon:					
Newport, Tenn	6	2	2	7.2	2
Tennessee:					
Knoxville, Tenn	12	3	4	16.2	4
Chattanooga, Tenn	33	....	....	32.3	5
Bridgeport, Ala	24	....	....	21.9	6
Guntersville, Ala	31	....	....	29.5	7
Florence, Ala	18	....	....	17.5	8–9
Riverton, Ala	32	5	11	35.5	9
Johnsonville, Tenn	31	....	....	28.0	6
Holston, N. Fork:					
Mendota, Va	8	2	3	10.0	2
Clinch:					
Clinton, Tenn	25	3	4	31.0	4
Powell:					
Tazewell, Tenn	20	3	3	20.8	3
Duck:					
Columbia, Tenn	30	2	3	31.5	3

[1] Continued from December. [2] December.

TABLE IV.—*Flood stages in the Mississippi drainage during January, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Mississippi:	Feet.			Feet.	
Arkansas City, Ark	42	19	21	42.2	20
Memphis, Tenn	35	....	....	31.3	17–18
Helena, Ark	42	....	....	39.0	18
Illinois:					
Morris, Ill	13	7	11	14.0	8
Peru, Ill	14	(1)	17	15.5	5
Henry, Ill	7	(1)	(2)	9.0	29–30
Peoria, Ill	16	(1)	....	15.9	[3] 31
Havana, Ill	14	....	....	13.0	1–2
Beardstown, Ill	12	(1)	4	12.5	1–2
St. Francis:					
Marked Tree, Ark	17	6	12	17.2	8–9
Ouachita:					
Arkadelphia, Ark	18	2	2	18.4	2
Camden, Ark	30	5	9	33.8	6
Atchafalaya:					
Melville, La	34	26	27	34.0	26–27
Petit Jean:					
Danville, Ark	20	....	....	18.9	3
White:					
Georgetown, Ark	22	3	5	22–3	3–4
Clarendon, Ark	30	....	....	28.5	8–9
Black:					
Black Rock, Ark	14	(1)	5	16.9	2
Cache:					
Jelks, Ark	9	(1)	23	11.1	2–3
Sulphur:					
Finley, Tex	24	....	....	23.6	5–6
Do	24	22	25	24.6	22–23
Ringo Crossing, Tex	20	....	....	18.3	20

[1] Continued from December. [3] December.
[2] Continued into February.

TABLE V.—*Flood stages in the west Gulf drainage during January, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Trinity:	Feet.			Feet.	
Dallas, Tex	25	18	20	31.9	19
Do	25	24	26	30.1	25
Trinidad, Tex	28	(1)	5	34.3	2
Do	28	30	(2)	28.3	31
Long Lake, Tex	40	....	....	36.9	1–2
Liberty, Tex	25	(1)	5	25.3	2–3
Sabine:					
Logansport, La	25	....	....	24.4	6
Merryville, La	20	....	....	19.5	24–25
Guadalupe:					
Victoria, Tex	16	24	26	19.6	25

[1] Continued from December. [2] Continued into February.

TABLE VI.—*Flood stages in the Pacific drainage during January, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Eel:	Feet.			Feet.	
Fernbridge, Cal	15	17	18	16.4	17
Willamette:					
Eugene, Oreg	10	18	19	11.5	19
Do	10	22	24	11.0	22
Albany, Oreg	20	24	24	20.0	24
Salem, Oreg	20	23	24	21.0	24
Oregon City, Oreg	10	19	28	14.4	24
Portland, Oreg	15	23	26	18.0	24
Santiam:					
Jefferson, Oreg	10	19	19	11.0	19
Do	10	22	23	13.0	22
Yamhill:					
McMinnville, Oreg	35	24	24	38.5	24
Clackamas:					
Cazadera, Oreg	12	16	16	13.0	16
Do	12	....	....	11.5	23
Tualatin:					
Tualatin, Oreg	18	25	25	18.0	25

MEAN LAKE LEVELS DURING JANUARY, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Feb. 4, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during January, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.26	580.80	572.19	246.09
Above or below—				
Mean stage of December, 1918	−0.16	−0.25	−0.02	+0.20
Mean stage of January, 1918	+0.35	+0.03	+0.30	+0.02
Average stage for January, last 10 years	+0.27	−0.95	+0.63	+0.81
Highest recorded January stage	−0.52	−1.87	−1.36	−1.51
Lowest recorded January stage	+1.38	+1.72	+1.23	+2.29
Average relation of the January level to—				
December level	−0.3	−0.2	−0.1	−0.1
February level	+0.2	±0.0	±0.0	−0.1

EFFECT OF WEATHER ON CROPS, JANUARY, 1919.

By J. WARREN SMITH, Meteorologist.

[Dated: Weather Bureau, Washington, Mar. 3, 1919.]

Plowing.—The mild and comparatively dry weather during the month permitted of much more plowing and other outdoor work than is usual for January. The preparation of the soil for planting spring crops was hindered, however, in much of the Gulf States by wet soil and this work at the close of the month was backward for the season.

Due to the warm weather, vegetation made considerable growth in the South and on the north Pacific coast, and much more than is usual for this month in the central districts. Cool nights and deficient moisture retarded growth in California, however, and the cold weather at the beginning of the month caused some damage in that State and also in the Gulf districts.

Wheat.—There was some damage to winter wheat by low temperatures the first of the month, particularly in the Southeast and on the north Pacific coast, but on the whole the mild weather after the first decade was decidedly favorable for winter grains, and wheat especially, made unusual growth. At the close of the month winter grains were in an unusually good condition.

Truck crops.—After the first few days of the month, when early truck crops were considerably damaged in the South by cold weather, conditions were decidedly favorable for winter truck, but wet soil delayed the planting of spring truck in southern districts.

Live stock.—Conditions were generally favorable for meadows, pastures, and live stock, but heavy snow which caused considerable loss of stock covered the ground in western Kansas, northern New Mexico, and the Texas Panhandle during the first of the month.

Fruit.—In the first few days of January, frost severely damaged lemons and oranges in California, and a large number of Satsuma orange trees were defoliated in Alabama; otherwise little damage to fruit was reported although some local injury was done to fruit buds in Colorado and Missouri.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 176 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, 75th Meridian time, and for about 30 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.80

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the excessive rate ends. In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred, the greatest precipitation of any single storm has been given; also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed at Washington by the method employed for reducing United States observations and described by Prof. F. H. Bigelow in this REVIEW, January, 1902, pages 13–16; the altitudes are those furnished us on January 1, 1916.

Chart I.—*Hydrographs* for several of the principal rivers of the United States.

Chart II.—*Tracks of centers of* HIGH areas; and

Chart III.—*Tracks of centers* of LOW areas. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th Meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea-level and standard gravity.

Chart IV.—*Temperature departures.* This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin R, Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908, have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—*Total precipitation.* The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—*Percentage of clear sky between sunrise and sunset.* The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—*Isobars and isotherms at sea-level, and prevailing wind directions.* The pressures have been reduced to sea-level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction $t_o - t$, or temperature on the sea-level plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sea-level temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only

Chart VIII.—*Total snowfall.* This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Chart IX.—*Meteorological conditions over the North Atlantic Ocean.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	44.5	− 1.2	2 stations	77	1	St. Bernard	−11	4	5.84	+1.07	Cochrane	11.11	Tuscumbia	3.33
Arizona	37.6	− 4.8	Sentinel	80	25	Chin Lee	−32	2	0.47	−0.95	Childs	2.20	4 stations	0.00
Arkansas	41.4	+ 0.1	Dardanelle	75	13	2 stations	− 3	4	3.00	−1.23	Sheridan	7.80	Rogers	0.32
California	46.3	+ 0.5	Indio	87	22	Alturas	−18	1	2.73	−2.68	Upper Mattole	22.92	4 stations	0.00
Colorado	21.0	− 3.9	Canon City	65	24	3 stations	−39	1	0.16	−0.85	Savage Basin	1.07	14 stations	0.00
Florida	57.8	− 0.8	Homestead	88	25†	Garniers (near)	14	4	2.32	−0.56	Garniers (near)	6.45	Ritta	0.05
Georgia	47.1	+ 0.8	Brunswick	79	1	2 stations	2	4	4.79	+0.99	Tallapoosa	8.03	Waycross	1.67
Hawaii (December)	69.7	+ 0.1	Waianae, Oahu	90	26†	2 stations	48	5	11.09	+2.50	Honokane, Hawaii	44.53	Kula Sanitarium	0.03
Idaho	26.0	+ 1.9	4 stations	62	21†	New Meadows	−28	1	1.64	−0.64	Wallace	8.20	2 stations	0.01
Illinois	31.7	+ 4.8	Carbondale	66	19†	Morrison	−28	4	0.46	−2.11	Palestine	1.77	2 stations	T.
Indiana	33.2	+ 4.3	Rome	66	20	La Porte	−14	4	1.02	−2.09	Rome	2.29	Veedersburg	T.
Iowa	26.8	+ 8.9	Centerville	64	19	Maquoketa	−32	4	0.24	−0.81	Nora Springs	0.86	6 stations	T.
Kansas	30.2	+ 0.8	Ellsworth	69	29	Salina	−25	3	0.07	−0.68	Wamego	0.49	28 stations	0.00
Kentucky	37.9	+ 2.7	3 stations	68	19†	Marion	− 1	4	3.62	−0.77	2 stations	7.10	Louisville	1.63
Louisiana	48.7	− 2.1	Houma	82	1	Newellton	6	4	6.33	+1.97	Napoleonville	8.80	Ruston	3.19
Maryland-Delaware	34.2	+ 3.2	College Park, Md	66	21	Oakland, Md	−19	5	3.50	+0.10	Seaford, Del	4.70	Westernport, Md	1.45
Michigan	26.2	+ 5.5	3 stations	59	18†	Sidnaw	−31	4	0.87	−1.21	Marquette	2.21	Omer	0.10
Minnesota	18.5	+10.2	Worthington	55	29	Itasca State Park	−45	3	0.38	−0.34	Redwood Falls	1.60	Tracy	0.05
Mississippi	44.9	− 2.2	2 stations	78	1†	Louisville	− 3	3	5.46	+0.78	Edwards	8.93	Pontotoc	1.35
Missouri	34.0	+ 3.6	Marble Hill	70	12	Maryville	−23	4	0.40	−1.88	New Madrid	4.47	Avalon	0.00
Montana	29.2	+10.6	Choteau	79	16	2 stations	−35	3	0.62	−0.48	Heron	5.91	4 stations	0.00
Nebraska	30.2	+ 8.6	Weeping Water	71	30	Ainsworth	−28	3	0.10	−0.47	Atkinson	0.75	25 stations	0.00
Nevada	30.0	+ 0.3	3 stations	70	12†	Owyhee	−24	1	0.17	−0.99	Marlette Lake	1.43	5 stations	0.00
New England	25.9	+ 4.8	Cavendish, Vt	61	17	Enosburg Falls, Vt	−27	12	3.11	−0.34	Kingston, R. I	5.96	Northfield, Vt	1.02
New Jersey	34.1	+ 4.3	2 stations	62	2	Culvers Lake	− 9	5†	3.51	−0.28	Atlantic City	4.44	Layton	2.24
New Mexico	26.0	− 7.4	3 stations	70	31	Dulse	−37	2	0.16	−0.51	Cloverdale	1.33	32 stations	0.00
New York	27.9	+ 5.1	New York City	60	1	North Lake	−27	11	2.01	−0.84	Adams Center	6.79	Avon	0.23
North Carolina	42.5	+ 1.6	Newbern	77	22	Banners Elk	− 7	4	4.75	+1.08	Highlands	8.53	Edenton	2.30
North Dakota	18.7	+13.8	Beach	66	25	Steele	−44	1	0.16	−0.38	Colgate	0.60	6 stations	0.00
Ohio	32.9	+ 4.4	Peebles	72	22	Millport	− 9	5	1.60	−1.62	Portsmouth	4.13	North Bass Island	0.48
Oklahoma	37.8	− 0.8	2 stations	72	11	Kenton	−20	1	0.74	−0.50	Antlers	3.45	Mutual	0.00
Oregon	35.7	+ 0.6	Grants Pass	71	22	Austin	−25	1	4.92	+0.76	Deadwood	24.63	Hampton	0.16
Pennsylvania	32.0	+ 4.1	Uniontown	64	1	Ebensburg	−15	5	2.53	−0.84	Somerset	4.94	Lawrenceville	1.00
Porto Rico	73.8	+ 0.6	San Salvador	97	12	3 stations	53	2†	3.56	0.00	Arecibo	7.85	2 stations	0.80
South Carolina	47.1	+ 1.6	Oaks	80	2	Landrum	8	4	4.15	+0.71	Liberty	8.50	Paris Island	0.30
South Dakota	27.3	+11.5	Bellefourche	66	18	Pollock	−39	3	0.12	−0.39	Harveys Ranch	1.40	14 stations	0.00
Tennessee	39.3	+ 0.5	Newport	74	1	2 stations	− 8	4	5.39	+0.88	Celina	8.23	Union City	2.49
Texas	45.3	− 3.1	McKinney	84	13	Dalhart	−17	1	3.09	+1.85	Anahuac	8.97	5 stations	0.00
Utah	24.5	− 1.0	Springdale	66	23	Hanksville	−35	2	0.09	−1.41	Silver Lake	0.72	27 stations	0.00
Virginia	38.4	+ 2.7	2 stations	71	21	Burkes Garden	−16	5	3.97	+0.67	Clarksville	6.04	Winchester	1.92
Washington	33.8	+ 3.3	Kennewick	68	23	2 stations	−10	1	6.17	+1.31	Wind River	23.82	Sunnyside	0.63
West Virginia	34.1	+ 1.1	Glenville	69	22	Terra Alta	−16	5	3.79	−0.18	Pickens	6.06	Upper Tract	1.60
Wisconsin	22.2	+ 7.8	Prairie du Sac	59	26	Hillsboro	−42	4	0.57	−0.64	Oconto	1.38	Solon Springs	0.10
Wyoming	24.3	+ 4.5	2 stations	64	17†	Sheridan Creek	−33	1	0.16	−0.66	Moran	1.36	16 stations	0.00

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

TABLE I.—*Climatological data for Weather Bureau stations, January, 1919.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with .01, or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England.							29.2	+5.1										77	3.24	−2.5										6.6		
Eastport	76	67	85	29.82	29.90	−0.10	24.2	+4.1	49	2	32	−10	12	16	39	23	20	85	3.06	−0.8	14	8,704	w.	52	e.	24	5	10	16	7.1	12.2	0.6
Greenville	1,070	6	...	28.71	29.92	...	15.6	...	37	2	24	−16	12	7	39	...	...	...	2.85	...	11	...	...	...	...	...	7	7	17	...	15.8	17.0
Portland, Me.	103	82	117	29.84	29.97	−.08	25.8	+3.8	43	16	33	−8	12	18	31	23	18	74	4.69	+0.9	11	6,771	sw.	48	nw.	24	7	7	17	6.9	8.8	1.2
Concord	288	70	79	29.64	29.97	−.08	24.7	+3.5	44	2	34	−7	7	15	34	...	...	...	3.05	−0.3	9	3,168	nw.	30	nw.	24	10	12	9	5.5	11.9	1.1
Burlington	404	11	48	29.53	30.00	−.05	23.0	+6.7	48	2	32	−11	10	14	35	...	...	...	1.18	−0.6	11	9,635	s.	60	s.	1	4	3	24	7.8	10.8	2.2
Northfield	876	12	60	29.00	29.99	−.06	21.1	+6.0	58	2	32	−15	10	10	44	18	15	82	1.02	−1.5	8	5,664	s.	33	sw.	2	3	10	18	7.3	6.8	5.0
Boston	125	115	188	29.83	29.97	−.08	33.2	+6.2	59	2	41	2	12	26	38	30	24	70	3.62	−0.2	8	7,984	w.	40	nw.	24	6	11	14	6.5	4.1	0.4
Nantucket	12	14	90	29.96	29.97	−.07	35.4	+3.3	52	2	41	8	12	30	26	33	30	82	4.83	+1.4	10	12,611	sw.	56	sw.	10	8	5	18	6.8	3.2	0.0
Block Island	26	11	46	29.96	29.99	−.08	35.1	+3.7	55	2	41	6	12	30	29	33	30	82	3.76	−0.1	11	15,610	nw.	60	w.	24	9	5	17	6.5	0.7	0.0
Providence	160	215	251	29.81	29.99	−.07	32.8	+5.6	58	2	40	2	12	25	32	29	24	73	4.34	0.0	9	9,998	nw.	79	nw.	24	6	12	13	6.4	2.0	0.0
Hartford	159	122	140	29.83	30.01	−.06	32.2	+6.7	56	2	40	2	12	25	29	28	23	71	2.95	−0.9	8	5,990	nw.	38	nw.	24	7	8	16	6.6	1.1	0.0
New Haven	106	117	155	29.90	30.02	−.06	33.8	+6.5	54	1	41	5	12	27	26	30	25	74	3.17	−0.7	8	6,987	sw.	38	w.	24	10	8	13	5.5	0.4	0.0
Middle Atlantic States.							36.4	+4.8										73	3.14	−0.1										5.4		
Albany	97	102	115	29.91	30.02	−.05	29.5	+7.0	56	2	37	−3	12	22	33	26	22	76	1.42	−1.2	8	5,587	s.	28	nw.	24	8	10	13	5.9	5.4	T.
Binghamton	871	10	69	29.06	30.02	−.06	30.0	+6.9	58	1	38	1	6	22	29				1.29	−0.7	8	4,608	nw.	28	nw.	9	6	12	13	6.4	5.5	T.
New York	314	414	454	29.69	30.04	−.06	35.2	+5.0	60	1	42	9	10	28	27	31	24	66	3.35	−0.4	7	13,912	nw.	84	nw.	24	9	8	14	6.3	0.3	0.0
Harrisburg	374	94	104	29.68	30.09	−.01	33.8	+5.1	59	21	42	5	5	26	30	29	23	70	2.75	−0.1	6	5,028	nw.	31	nw.	24	9	11	11	5.3	9.0	0.0
Philadelphia	117	123	190	29.95	30.08	−.03	37.7	+5.9	61	1	44	13	12	31	26	34	31	80	3.35	−0.1	8	8,089	sw.	41	nw.	10	14	8	9	4.7	0.5	0.0
Reading	325	81	98	29.73	30.10	...	34.2	...	59	1	42	7	5	27	25	30	24	71	3.24	−0.3	8	4,903	nw.	36	nw.	24	10	11	10	5.4	4.7	0.0
Scranton	805	111	119	29.17	30.06	−.03	31.7	+6.2	56	1	40	3	5	24	28	29	27	85	2.44	−0.4	12	4,752	sw.	36	nw.	24	6	14	11	6.1	10.5	0.0
Atlantic City	52	37	48	30.01	30.07	−.04	37.4	+4.9	54	1	44	12	12	30	25	33	30	78	4.44	+1.0	8	5,740	nw.	32	nw.	24	16	4	11	4.6	0.9	0.0
Cape May	18	13	49	30.08	30.10	−.02	37.6	+3.5	55	2	44	12	12	32	22	35	...	...	3.54	+0.2	11	...	nw.	...	...	...	16	8	7	...	1.3	0.0
Sandy Hook	22	10	57	30.03	30.05	...	35.0	...	58	1	41	12	10	29	23	32	29	78	2.94	...	8	12,744	w.	58	w.	24	14	6	11	5.0	T.	0.0
Trenton	190	159	183	29.83	30.04	...	34.8	...	60	1	42	9	12	27	26	31	26	73	3.28	+0.1	7	9,019	sw.	46	nw.	24	12	10	9	5.3	0.3	0.0
Baltimore	123	100	113	29.96	30.09	−.03	38.2	+4.8	64	1	46	11	5	30	25	33	27	67	3.51	+0.3	7	3,994	sw.	20	sw.	31	13	9	9	5.1	1.0	0.0
Washington	112	62	85	29.97	30.10	−.03	38.1	+5.2	64	1	46	11	5	30	28	32	26	67	3.47	+0.1	9	5,133	nw.	35	nw.	29	12	10	9	5.0	0.5	0.0
Lynchburg	681	153	188	29.35	30.11	−.02	41.0	+5.2	68	22	52	10	4	30	39	34	29	68	4.11	+0.4	7	6,020	nw.	37	nw.	9	15	10	6	4.7	T.	0.0
Norfolk	91	170	205	30.01	30.12	−.01	43.8	+3.4	68	21	52	22	10	36	25	38	33	74	3.10	−0.3	9	9,340	sw.	44	w.	23	14	8	9	4.8	4.5	0.0
Richmond	144	11	52	29.96	30.12	−.01	40.6	+2.6	66	21	51	15	5	30	33	35	29	71	3.64	+0.6	9	5,711	sw.	30	nw.	29	11	9	11	5.4	T.	0.0
Wytheville	2,293	49	55	27.68	30.15	−.01	35.1	+2.1	60	22	44	0	5	26	36	29	24	72	3.30	−1.0	8	4,946	w.	31	sw.	30	17	4	10	4.2	4.8	0.0
South Atlantic States.							47.8	+2.6										74	3.52	−0.3										4.9		
Asheville	2,255	70	84	27.74	30.18	+.03	37.6	+2.2	64	21	48	0	4	27	35	32	27	71	4.70	0.0	10	6,442	nw.	38	se.	1	18	4	9	4.2	2.2	0.0
Charlotte	773	153	161	29.27	30.13	−.02	45.0	+4.6	70	1	55	15	6	35	30	38	33	72	5.45	+1.2	8	3,826	n.	28	nw.	29	12	12	7	4.9	T.	0.0
Hatteras	11	12	50	30.09	30.10	−.04	47.8	+2.0	69	2	54	28	4	42	28	44	41	83	4.84	−0.1	13	10,072	n.	44	n.	5	13	6	12	5.2	T.	0.0
Manteo	12	4	46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Raleigh	376	103	110	29.71	30.13	.00	45.2	+4.8	70	22	55	15	5	35	28	40	36	78	3.14	−0.4	8	5,442	sw.	33	nw.	29	13	6	12	4.9	0.0	0.0
Wilmington	78	81	91	30.04	30.13	−.01	49.2	+3.6	75	2	59	20	6	40	30	42	37	72	3.23	−0.3	10	4,745	n.	29	sw.	23	13	8	10	4.5	T.	0.0
Charleston	48	11	92	30.07	30.12	−.03	51.1	+1.8	70	23	59	22	4	43	34	45	40	75	1.68	−1.8	8	7,037	n.	30	sw.	18	14	6	11	5.0	0.0	0.0
Columbia, S. C.	351	41	57	29.75	30.14	−.01	47.6	+2.5	75	1	58	18	6	37	32	41	35	68	3.81	+0.5	8	4,665	ne.	29	sw.	1	15	7	9	4.5	0.0	0.0
Augusta	180	62	77	29.94	30.14	−.02	47.6	+1.7	73	1	58	16	4	37	32	41	38	78	4.64	+0.5	8	3,807	nw.	22	nw.	3	9	9	13	5.6	0.0	0.0
Savannah	65	150	194	30.06	30.12	−.03	51.9	+2.0	74	1	61	20	4	43	28	45	40	71	1.96	−1.2	6	8,693	ne.	39	nw.	4	14	5	12	5.2	0.0	0.0
Jacksonville	43	200	245	30.07	30.12	−.03	55.3	+1.4	75	21	64	23	4	47	32	49	45	78	1.73	−1.4	7	9,379	nw.	32	s.	23	8	13	10	5.6	0.0	0.0
Greenville, S. C.	1,013	113	122	29.00	30.11	...	45.1	...	68	31	55	12	4	35	39	38	31	66	6.53	...	8	5,163	ne.	38	nw.	29	16	6	9	4.0	T.	0.0
Florida Peninsula.							64.3	−1.1										79	1.42	−1.0										5.7		
Key West	22	10	64	30.04	30.06	−0.04	68.1	−0.7	80	3	73	52	6	64	17	63	60	82	0.74	−1.2	5	8,139	n.	34	nw.	4	11	12	8	4.6	0.0	0.0
Miami	25	71	79	30.05	30.08	...	65.1	−2.2	78	24	72	37	5	59	23	60	57	80	1.07	−1.4	9	6,695	nw.	26	nw.	5	11	8	12	6.0	0.0	0.0
Tampa	35	79	92	30.07	30.11	−.01	59.7	−0.4	78	23	68	33	6	52	26	53	49	76	2.44	−0.4	6	5,172	nw.	21	sw.	17	5	13	13	6.4	0.0	0.0
East Gulf States.							46.9	−0.4										75	5.68	+0.7										5.2		
Atlanta	1,174	190	216	28.89	30.15	.00	43.8	+1.5	66	1	52	5	4	36	24	38	33	70	5.40	+0.1	8	8,609	nw.	42	nw.	3	16	4	11	4.5	0.3	0.0
Macon	370	78	87	29.74	30.15	−.01	46.2	+0.6	72	1	57	12	4	35	35	40	35	72	5.01	−0.2	9	4,401	nw.	24	s.	1	12	10	9	4.7	0.0	0.0
Thomasville	273	49	58	29.83	30.13	−.03	51.4	+0.4	72	21	61	18	4	42	30	44	39	71	2.32	−1.8	6	3,388	n.	18	sw.	17	12	6	13	5.4	T.	0.0
Pensacola	56	149	185	30.09	30.15	+.01	50.1	−2.2	69	1	57	17	4	43	22	46	42	78	5.94	+1.9	8	9,785	n.	60	s.	16	10	8	13	5.5	T.	0.0
Anniston	741	9	57	29.37	30.18	+.02	42.2	0.0	72	1	53	4	4	31	39	...	...	...	6.36	+1.0	10	3,882	nw.	22	s.	1	12	11	8	4.5	4.4	0.0
Birmingham	700	11	48	29.40	30.19	+.03	43.9	−1.4	71	1	54	4	4	34	30	37	32	70	6.21	+0.9	11	4,208	n.	28	s.	1	14	8	9	4.5	6.4	0.0
Mobile	57	125	161	30.09	30.15	.00	49.6	−0.2	67	1	58	17	4	41	30	44	39	73	6.57	+1.7	10	7,196	n.	34	n.	2	12	6	13	5.6	T.	0.0
Montgomery	223	100	112	29.92	30.18	+.02	47.0	−0.7	76	1	56	13	4	38	29	41	37	75	5.03	−0.1	8	4,448	e.	23	sw.	1	12	8	11	5.1	0.5	0.0
Corinth	469	6	...	...	...	...	42.4	...	68	30	54	9	3	31	36	...	...	...	5.00	...	9	...	s.	...	...	...	7	13	11	...	0.4	0.0
Jackson	304	5	...	...	...	...	45.2	...	70	1	56	4	4	34	39	...	...	...	6.16	...	11	...	se.	...	...	...	10	12	9	...	10.0	0.0
Meridian	375	85	93	29.76	30.18	+.02	44.5	−0.5	72	1	55	10	4	34	35	39	35	77	6.31	+0.8	11	3,375	n.	25	ne.	23	13	9	9	5.1	3.8	0.0
Vicksburg	247	65	74	29.90	30.20	+.05	46.4	−0.6	70	1	55	10	4	38	36	41	37	76	5.28	−0.4	11	4,508	se.	26	nw.	1	7	8	16	6.4	10.1	0.0
New Orleans	51	76	84	30.10	30.16	+.03	51.2	−1.8	76	1	58	23	4	45	27	47	45	84	8.03	+3.4	10	4,405	n.	25	nw.	3	9	8	14	6.2	0.0	0.0
West Gulf States.							46.4	+0.3										77	3.08	+0.1										5.4		
Shreveport	249	77	93	29.92	30.20	+.06	46.0	−0.2	66	13	54	16	4	38	30	41	36	75	3.28	−1.1	9	4,732	nw.	27	se.	22	16	2	13	4.9	0.1	0.0
Bentonville	1,302	11	44	28.75	30.16	+.02	37.4	+3.3	64	19	48	−2	3	27	33	...	...	...	0.68	−2.0	6	3,787	s.	20	s.	12	17	6	8	4.1	2.5	0.0
Fort Smith	457	79	94	29.68	30.17	+.03	41.4	+3.1	66	21	51	7	3	32	32	36	31	72	1.51	−1.0	7	5,167	e.	28	nw.	5	16	5	10	4.2	1.2	0.0
Little Rock	357	139	147	29.78	30.18	+.03	43.2	+2.6	66	29	52	10	4	35	29	38	32	69	2.72	−2.1	6	6,029	nw.	30	nw.	1	11	9	11	5.3	T.	0.0
Brownsville	57	4	26	...	...	...	56.0	...	79	20	67	24	4	46	40	...	...	...	4.56	...	14	...	n.	...	...	...	...	...	...	...	...	...
Corpus Christi	20	69	77	30.16	30.18	+.08	52.2	−1.3	70	1	58	30	4	46	35	48	46	84	3.99	+1.7	14	6,153	nw.	37	se.	1	11	2	18	6.4	0.0	0.0
Dallas	512	109	117	29.61	30.18	...	44.8	...	67	21	54	17	3	36	30	...	...	...	1.80	...	10	5,708	nw.	31	s.	12	9	13	9	5.1	0.2	0.0
Fort Worth	670	106	114	29.44	30.17	+.05	45.8	+1.5	67	21	55	16	3	37	32	42	39	80	3.03	+2.1	8	7,220	nw.	28	nw.	1	11	10	10	5.1	T.	0.0
Galveston	54	106	114	30.12	30.18	+.05	50.6	−2.1	66	14	55	28	4	46	30	47	45	86	6.22	+2.6	10	7,926	n.	37	n.	1	10	3	18	6.2	T.	0.0
Houston	138	111	121	30.02	30.18	...	50.6	−2.3	73	21	58	24	3	43	27	...	...	...	8.52	...	11	5,508	nw.	22	nw.	1	9	7	15	5.9	T.	0.0
Palestine	510	64	72	29.64	30.18	+.06	46.9	+0.4	66	21	55	18	4	39	27	42	38	79	2.54	−1.3	7	4,755	s.	20	ne.	15	9	8	14	5.9	0.1	0.0
Port Arthur	34	58	66	30.12	30.16	...	49.2	...	68	21	56	22	4	42	29	45	43	85	6.13	...	10	6,053	n.	32	s.	1	10	9	12	5.6	T.	0.0
San Antonio	701	119	132	29.43	30.18	+.08	49.7	−1.4	71	25	58	24	4	41	29	44	39	74	3.78	+2.1	9	5,525	n.	30	w.	21	9	7	15	5.9	0.0	0.0
Taylor	582	55	63	29.57	30.19	+.08	46.8	−0.7	70	21	56	19	3	38	36	...	...	...	3.07	+0.2	8	6,320	nw.	32	s.	21	10	7	14	5.9	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, January, 1919*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure. Station, reduced to mean of 2 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air. Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation. Total.	Departure from normal.	Days with .01, or more.	Wind. Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee.							**36.8**	**+3.8**										**74**	**2.66**	**−1.2**										**5.4**		
Chattanooga	762	189	213	29.36	30.19	+ .03	41.4	+0.8	66	1	50	4	4	32	29	35	29	68	6.13	+0.6	12	5,098	nw.	33	nw.	18	12	9	10	5.0	11.0	0.0
Knoxville	996	102	111	29.07	30.16	+ .01	39.1	+1.6	69	1	48	3	4	30	29	35	30	76	4.67	−0.3	12	3,466	ne.	36	s.	1	10	9	12	5.7	5.4	0.0
Memphis	399	76	97	29.77	30.21	+ .05	43.0	+2.7	65	21	50	11	4	36	21	39	35	77	3.77	−1.4	8	5,711	s.	25	nw.	3	10	6	15	5.9	0.1	0.0
Nashville	546	168	191	29.59	30.19	+ .03	40.1	+2.1	65	30	49	5	4	31	36	35	29	71	4.71	−0.1	8	5,561	nw.	30	s.	1	16	4	11	4.8	0.1	0.0
Lexington	989	193	230	29.06	30.16	+ .03	36.9	+3.9	63	22	45	3	3	29	32	....	....	....	2.48	−1.4	7	9,561	sw.	35	s.	1	13	8	10	5.0	1.7	0.0
Louisville	525	219	255	29.57	30.17	+ .03	38.5	+4.2	63	22	46	6	3	31	34	33	28	70	1.63	−2.3	6	7,783	s.	30	w.	28	15	6	10	4.6	T.	0.0
Evansville	431	139	175	29.69	30.17	+ .03	38.5	+6.2	62	22	46	5	4	31	25	34	29	73	1.14	−2.6	10	7,960	sw.	32	sw.	6	12	8	11	5.2	1.0	0.0
Indianapolis	822	194	230	29.21	30.12	.00	34.0	+5.8	59	20	42	− 2	4	26	31	30	26	77	0.91	−1.9	4	8,700	sw.	34	w.	1	10	8	13	5.6	0.1	0.0
Terre Haute	575	96	129	29.49	30.12	......	34.2	......	58	20	42	− 2	4	26	26	30	26	77	0.98	......	6	6,997	s.	27	sw.	10	8	16	7	5.1	0.7	0.0
Cincinnati	628	11	51	29.44	30.15	+ .03	35.2	+4.9	61	22	44	1	4	26	32	30	26	74	1.44	−1.9	6	5,764	sw.	23	sw.	1	12	8	11	5.2	0.2	0.0
Columbus	824	173	222	29.22	30.12	+ .01	33.1	+4.5	60	22	41	3	4	25	29	30	25	74	1.28	−1.7	5	8,800	w.	38	nw.	9	8	13	10	5.5	0.4	0.0
Dayton	899	181	216	29.11	30.10	......	34.4	+5.5	60	22	42	1	4	26	30	30	26	77	0.97	−2.0	3	7,707	sw.	33	n.	9	12	12	7	5.1	0.7	0.0
Pittsburgh	842	353	410	29.17	30.11	.00	34.4	+3.7	61	22	42	1	4	26	29	30	25	73	1.42	−1.4	8	8,882	sw.	43	nw.	9	9	4	18	6.1	3.7	0.0
Elkins	1,940	41	50	28.02	30.16	+ .04	31.6	+2.6	61	1	43	−14	5	20	40	27	23	80	4.20	+0.9	12	3,951	w.	26	w.	9	6	10	15	6.5	13.7	0.0
Parkersburg	638	77	84	29.47	30.15	+ .03	35.6	+4.3	63	22	45	5	4	26	30	31	26	73	2.48	−0.7	9	4,148	se.	34	w.	9	12	5	14	5.9	3.4	0.0
Lower Lake Region.							**30.4**	**+6.1**										**76**	**1.19**	**−1.5**										**6.3**		
Buffalo	767	247	280	29.16	30.01	−.06	31.0	+6.3	56	1	37	5	12	25	29	28	24	77	1.28	−2.0	11	16,711	sw.	78	sw.	10	4	8	19	7.5	7.8	T.
Canton	448	10	61	29.47	29.97	......	22.0	+5.7	51	1	31	−17	10	13	48	....	....	....	1.37	−1.8	13	8,543	sw.	43	w.	10	7	6	18	7.1	10.9	1.2
Oswego	335	76	91	29.62	30.00	−.07	28.7	+4.8	54	1	36	− 1	12	22	32	27	24	81	1.29	−1.9	11	9,486	s.	43	w.	10	5	6	20	7.3	15.8	2.0
Rochester	523	97	113	29.43	30.02	−.05	31.0	+7.0	54	21	38	3	12	24	31	27	22	72	0.95	−2.2	8	8,002	sw.	39	w.	10	7	4	20	6.9	6.8	0.3
Syracuse	597	97	113	29.36	30.02	−.05	29.9	+6.9	59	1	38	− 1	12	22	34	....	....	....	2.09	0.0	14	9,511	s.	48	nw.	24	7	6	18	7.0	19.0	3.0
Erie	714	130	166	29.25	30.04	−.04	31.9	+5.4	56	21	39	5	4	25	26	29	25	75	1.18	−1.8	10	12,762	sw.	43	sw.	10	8	11	12	6.1	6.2	0.0
Cleveland	762	190	201	29.23	30.08	−.01	32.6	+6.4	56	20	39	5	4	26	27	29	25	75	0.63	−1.8	8	11,306	sw.	48	nw.	9	10	9	12	5.9	1.3	0.0
Sandusky	629	62	103	29.36	30.07	−.02	32.7	+6.4	58	21	40	4	4	26	27	....	....	....	0.74	−1.4	8	10,624	sw.	44	nw.	9	8	10	13	6.2	0.7	0.0
Toledo	628	208	243	29.37	30.08	−.01	32.6	+7.0	57	21	40	3	3	25	27	29	24	73	0.77	−1.2	5	11,892	sw.	52	sw.	10	12	8	11	4.9	0.5	0.0
Fort Wayne	856	113	124	29.15	30.10	......	31.4	+4.5	57	21	39	− 4	4	24	33	28	24	76	0.72	......	5	8,151	sw.	36	sw.	10	10	12	9	5.3	0.4	0.0
Detroit	730	218	245	29.24	30.05	−.03	31.0	+6.7	51	21	38	4	4	24	25	28	25	79	0.91	−1.1	6	9,899	w.	54	w.	10	9	11	11	5.5	1.7	0.0
Upper Lake Region.							**25.8**	**+ 7.5**										**82**	**0.83**	**−1.3**										**6.8**		
Alpena	609	13	92	29.28	29.97	−.07	25.0	+ 6.3	42	16	31	− 5	5	19	25	23	20	83	0.63	−1.6	9	8,940	w.	42	nw.	9	6	5	20	7.2	5.7	T.
Escanaba	612	54	60	29.29	29.98	−.07	23.4	+ 8.9	40	25	29	− 4	4	18	25	22	20	86	0.69	−0.9	11	6,899	nw.	35	nw.	8	8	10	13	6.2	7.9	T.
Grand Haven	632	54	92	29.32	30.02	−.05	30.0	+ 5.5	46	21	35	4	3	25	30	28	25	82	1.62	−1.2	13	10,593	w.	42	nw.	9	6	8	17	6.8	16.4	0.0
Grand Rapids	707	70	87	29.24	30.04	−.02	30.0	+ 6.2	51	21	36	0	3	24	27	27	24	83	0.30	−2.5	10	5,335	sw.	25	nw.	9	6	8	17	7.1	4.6	0.0
Houghton	684	62	99	29.19	29.94	−.11	23.3	+ 8.8	45	15	29	2	4	18	28	....	....	....	1.13	−0.9	15	7,793	w.	45	nw.	8	3	7	21	8.3	11.3	4.8
Lansing	878	11	62	29.07	30.04	......	28.5	+ 6.5	52	21	35	− 2	3	22	23	25	22	82	0.36	−1.7	10	5,867	sw.	26	w.	10	7	9	15	6.3	1.3	0.0
Ludington	637	60	66	29.29	30.01	......	29.0	......	45	21	34	2	5	24	29	27	25	84	1.06	......	13	9,404	w.	50	sw.	8	5	7	19	7.5	15.5	0.0
Marquette	734	77	111	29.14	29.97	−.07	24.6	+ 8.7	45	20	30	3	4	19	23	23	20	83	2.21	+0.2	14	8,103	w.	40	nw.	8	1	10	20	7.9	25.3	8.6
Port Huron	638	70	120	29.30	30.02	−.04	29.4	+ 7.6	51	21	36	5	9	23	29	27	24	84	0.85	−1.0	6	9,456	w.	46	nw.	9	4	16	11	6.5	1.6	T.
Saginaw	641	48	82	29.30	30.01	......	28.2	......	46	27	34	− 1	5	22	22	25	23	83	0.29	−2.0	5	8,406	sw.	40	nw.	9	7	10	14	6.4	1.0	0.0
Sault Ste. Marie	614	11	61	29.25	29.97	−.06	20.4	+ 7.1	38	22	27	−13	4	14	33	19	16	84	1.05	−1.1	16	7,334	se.	44	nw.	10	2	6	23	8.4	12.4	5.0
Chicago	823	140	310	29.16	30.07	−.03	31.0	+ 7.3	52	20	37	−11	4	25	26	28	23	70	0.20	−1.8	2	10,352	w.	38	sw.	10	11	10	10	5.2	2.0	0.0
Green Bay	617	109	144	29.31	30.00	−.06	23.8	+ 9.2	44	27	30	−18	4	17	28	22	18	78	0.67	−1.0	7	8,689	sw.	40	nw.	9	11	6	14	6.5	8.5	0.0
Milwaukee	681	119	133	29.27	30.03	−.05	27.5	+ 7.7	51	27	34	−14	4	21	22	25	22	83	0.15	−1.9	2	7,984	w.	35	sw.	8	11	7	13	5.7	4.3	0.0
Duluth	1,133	11	47	28.71	29.99	−.10	17.8	+ 7.4	39	8	24	−22	3	11	35	16	14	90	0.46	−0.5	4	10,412	sw.	51	w.	8	11	8	12	5.6	5.9	4.1
North Dakota.							**19.7**	**+15.7**										**80**	**0.15**	**−0.4**										**5.1**		
Moorhead	940	8	57	28.98	30.05	−.09	15.7	+13.0	41	17	24	−35	3	7	31	15	11	84	0.21	−0.5	5	6,499	nw.	28	nw.	8	15	9	7	4.4	2.1	0.6
Bismarck	1,674	8	57	28.19	30.05	−.08	24.4	+17.7	52	19	36	−35	1	13	59	21	18	79	0.09	−0.4	4	7,283	nw.	40	nw.	4	11	14	6	5.0	0.9	T.
Devils Lake	1,482	11	44	28.34	29.98	−.14	14.4	+14.1	44	19	24	−34	3	5	43	13	11	89	0.22	−0.4	4	7,877	w.	33	nw.	27	13	6	12	5.1	2.9	3.0
Ellendale	1,457	10	56	28.41	30.03	......	20.8	......	48	29	31	−33	3	11	44	18	16	86	0.06	......	3	10,577	nw.	52	nw.	16	10	10	11	5.1	0.6	T.
Grand Forks	835	12	89	......	......	......	12.1	......	38	17	22	−36	1	2	37	12	....	....	0.45	......	4	......	w.	30	nw.	8	15	6	10	....	5.2	4.7
Williston	1,872	41	48	27.93	29.97	−.14	24.4	+17.9	51	23	34	−30	2	15	56	21	16	70	0.07	−0.5	4	6,200	sw.	42	nw.	3	8	14	9	5.8	0.6	T.
Upper Mississippi Valley.							**29.2**	**+7.7**										**79**	**0.25**	**−1.5**										**4.7**		
Minneapolis	918	10	208	28.98	30.00	......	22.2	......	45	29	30	−23	3	15	37	....	....	....	0.43	−0.3	6	8,147	w.	40	nw.	8	10	12	9	5.4	4.6	T.
St. Paul	837	201	236	29.08	30.02	−.09	21.8	+10.2	44	29	30	−23	3	14	40	....	....	....	0.44	−0.5	6	8,704	sw.	42	nw.	8	9	13	9	5.1	6.2	T.
La Crosse	714	11	48	29.24	30.04	−.07	24.2	+ 9.0	52	27	32	−26	4	16	38	....	....	....	0.31	−0.8	3	3,972	w.	24	nw.	8	12	4	15	5.8	10.0	0.0
Madison	974	70	78	28.96	30.06	−.04	24.1	+ 7.6	48	27	31	−23	4	17	28	22	19	82	0.26	−1.3	4	6,911	w.	31	sw.	10	9	6	16	6.4	4.3	0.0
Wausau	1,247	4	....	28.61	29.99	......	21.3	......	46	27	28	−21	4	14	29	....	....	....	0.31	......	8	......	nw.	......	......		13	1	17	5.6	4.1	T.
Charles City	1,015	10	49	28.94	30.07	−.07	24.0	+12.6	51	24	33	−23	3	15	38	21	19	87	0.22	−0.8	4	4,690	nw.	22	nw.	25	10	15	6	4.9	5.8	0.0
Davenport	606	71	79	29.41	30.10	−.02	27.8	+ 7.0	56	24	36	−16	4	20	30	25	22	84	0.07	−1.5	3	5,447	w.	23	w.	7	14	10	7	4.4	2.0	0.0
Des Moines	861	84	97	29.14	30.09	−.05	29.8	+ 9.4	62	29	39	−17	3	21	37	26	22	80	0.08	−1.1	3	5,192	nw.	24	nw.	7	15	8	8	4.0	2.5	0.0
Dubuque	698	81	96	29.31	30.09	−.03	25.9	+ 7.6	51	24	34	−23	4	18	33	23	20	82	0.17	−1.3	4	4,472	nw.	23	nw.	8	9	12	10	5.2	2.3	0.0
Keokuk	614	64	78	29.43	30.14	.00	30.7	+ 7.0	60	24	40	−18	3	22	33	23	22	75	0.01	−1.7	1	5,325	sw.	24	s.	8	20	9	2	2.6	0.1	0.0
Cairo	356	87	93	29.76	30.16	.00	39.4	+ 4.6	63	20	47	4	4	32	24	34	29	72	1.15	−2.7	8	5,570	s.	28	n.	9	13	5	13	5.4	0.7	0.0
Peoria	609	11	45	29.43	30.12	.00	29.2	+ 6.1	55	24	38	−14	3	20	27	26	23	86	0.07	−2.1	3	5,149	w.	22	sw.	16	18	6	7	3.8	0.3	0.0
Springfield, Ill	644	10	91	29.41	30.11	−.02	32.8	+ 5.5	55	20	41	− 8	3	25	27	27	22	77	0.09	−2.2	3	6,206	w.	23	sw.	10	11	10	10	4.9	0.9	0.0
Hannibal	534	74	109	29.53	30.12	−.01	32.3	+ 5.6	61	29	42	−12	3	23	33	....	....	....	0.02	−2.2	3	6,186	sw.	28	sw.	10	18	7	6	3.5	0.6	0.0
St. Louis	567	265	303	29.51	30.13	−.01	37.8	+ 6.8	62	20	46	− 3	3	30	31	33	26	66	0.13	−2.1	5	9,400	nw.	37	s.	10	19	10	2	2.9	0.7	0.0
Missouri Valley.							**31.7**	**+10.7**										**75**	**0.11**	**−0.9**										**3.6**		
Columbia, Mo.	781	11	84	29.28	30.14	+ .01	34.2	+ 7.0	63	24	43	−11	3	25	33	....	....	....	0.07	−2.2	1	5,530	sw.	26	nw.	7	20	6	5	3.0	0.9	0.0
Kansas City	963	161	181	29.07	30.14	+ .01	34.4	+ 8.2	63	29	42	−13	3	26	30	30	25	71	0.07	−1.1	1	7,825	s.	31	n.	4	23	1	7	2.8	1.0	0.0
St. Joseph	967	11	49	29.05	30.12	......	31.8	......	61	29	41	−16	3	23	27	28	24	77	0.03	......	1	5,499	sw.	29	nw.	7	20	5	6	3.0	0.3	0.0
Springfield, Mo.	1,324	98	104	28.71	30.16	+ .02	36.6	+ 5.3	62	19	45	− 6	3	28	27	31	27	73	0.34	−2.3	5	6,611	s.	23	nw.	7	18	6	7	3.8	3.6	0.0
Iola	984	11	50	29.07	30.16	+ .02	33.6	+ 6.0	64	29	43	−10	3	24	33	....	....	....	0.02	−1.0	1	4,308	s.	19	s.	24	22	3	6	3.3	0.2	0.0
Topeka	983	85	101	......	......	......	32.6	+ 7.0	65	29	42	−15	3	23	32	....	....	....	0.06	−0.9	1	6,443	sw.	30	nw.	4	21	5	5	2.9	1.0	0.0
Drexel	1,299	10	54	28.64	30.07	......	29.6	......	61	29	40	−20	3	20	33	26	23	83	0.12	......	2	7,928	nw.	27	nw.	4	18	7	6	3.9	2.2	0.0
Lincoln	1,189	11	84	28.79	30.10	−.05	32.9	+11.7	66	29	43	−16	3	23	33	28	23	74	0.03	−0.6	1	4,647	sw.	33	n.	4	16	10	5	4.0	0.5	0.0
Omaha	1,105	115	122	28.88	30.10	−.05	31.9	+11.4	62	29	40	−18	3	23	29	28	23	74	0.10	−0.6	2	5,216	nw.	35	nw.	4	15	8	8	4.1	2.9	0.0
Valentine	2,598	47	54	27.29	30.10	−.02	30.2	+12.0	58	29	43	−21	3	18	51	25	21	74	0.06	−0.5	2	6,906	w.	36	nw.	4	20	7	4	3.4	0.7	0.0
Sioux City	1,135	94	164	28.82	30.08	−.07	29.2	+13.6	58	29	38	−22	3	20	31	25	20	74	0.26	−0.3	3	8,153	nw.	42	nw.	4	15	8	8	3.9	4.8	0.0
Huron	1,306	59	74	28.63	30.08	−.08	25.6	+16.1	55	29	35	−27	3	16	36	23	19	80	0.11	−0.4	2	7,579	nw.	40	n.	4	17	7	7	3.9	1.1	0.0
Pierre	1,572	70	75	28.34	30.06	−.07	29.7	+15.8	60	29	41	−23	3	19	54	26	20	71	0.04	−0.4	1	5,028	nw.	40	nw.	4	17	8	6	3.7	0.4	0.0
Yankton	1,233	49	57	28.70	30.07	−.09	29.4	+13.9	58	29	40	−22	3	19	31	....	....	....	0.15	−0.4	3	5,549	nw.	36	nw.	4	11	14	6	4.8	3.3	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, January, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01, or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Northern Slope.							**29.5**	**+10.5**										**65**	**0.25**	**−0.6**										**4.3**		
Billings	3,140	5	....	......	......	......	34.7	......	67	23	48	−5	2	21	44	....	....	....	0.04	......	1	......	sw.	....	......	....	16	14	1	....	0.5	0.0
Havre	2,505	11	44	27.29	29.98	−.12	34.1	+20.6	61	23	44	−14	1	24	35	29	23	66	0.40	−0.3	4	8,680	sw.	43	w.	15	13	13	5	4.4	1.4	0.0
Helena	4,110	87	114	25.81	30.12	−.03	32.4	+12.4	57	18	41	−3	1	24	32	26	17	52	0.14	−0.8	7	6,682	sw.	40	sw.	19	9	8	14	6.0	1.4	0.0
Kalispell	2,962	11	34	26.97	30.13	+.01	26.8	+7.2	54	18	34	−6	1	19	30	24	22	82	0.72	−0.9	9	3,127	nw.	37	sw.	15	5	7	19	7.5	3.9	0.0
Miles City	2,371	26	48	27.46	30.09	−.03	32.6	+18.1	64	23	44	−22	2	21	47	27	24	80	0.02	−0.6	2	4,386	se.	28	nw.	6	13	17	1	3.3	0.4	0.0
Rapid City	3,259	50	58	26.60	30.10	.00	34.9	+13.4	64	17	48	−13	2	22	51	26	15	49	0.04	−0.4	1	6,495	w.	44	nw.	4	19	9	3	3.5	0.4	0.0
Cheyenne	6,088	84	101	24.00	30.12	+.07	31.8	+6.2	60	10	42	−2	1	21	34	24	13	47	T.	−0.4	0	13,116	w.	58	w.	17	16	11	4	3.8	T.	T.
Lander	5,372	60	68	24.69	30.27	+.15	22.2	+4.8	55	23	38	−18	2	7	43	17	10	64	0.00	−0.4	0	2,302	sw.	30	nw.	15	16	11	4	3.9	0.0	T.
Sheridan	3,790	10	47	26.10	30.14	......	28.0	......	62	23	43	−15	2	13	44	22	15	66	0.33	......	4	3,299	nw.	34	nw.	23	16	10	5	3.4	7.4	0.0
Yellowstone Park	6,200	11	48	23.94	30.30	+.16	22.2	+4.6	40	19	31	−5	1	13	33	18	13	71	0.88	−1.4	13	6,705	s.	40	s.	16	11	9	11	4.8	10.0	1.6
North Platte	2,821	11	51	27.14	30.18	+.06	28.6	+7.2	62	29	41	−17	3	16	45	23	19	75	0.03	−0.4	2	4,324	w.	33	w.	4	25	3	3	2.1	0.6	0.0
Middle Slope.							**33.4**	**+4.4**										**72**	**0.09**	**−0.6**										**2.5**		
Denver	5,292	106	113	24.75	30.15	+.10	34.2	+5.1	58	23	46	−12	1	23	33	27	20	59	0.12	−0.3	1	6,054	s.	28	w.	5	18	10	3	3.2	1.8	0.0
Pueblo	4,685	80	86	25.35	30.19	+.14	30.8	+1.7	64	23	45	−20	1	17	44	24	19	69	0.03	−0.3	1	3,646	nw.	27	w.	24	19	6	6	3.2	0.4	0.0
Concordia	1,392	50	58	28.62	30.14	.00	33.6	+9.2	60	29	43	−14	3	24	30	29	25	79	0.02	−0.7	2	5,235	sw.	36	nw.	4	19	9	3	3.3	0.3	0.0
Dodge City	2,509	11	51	27.47	30.18	+.07	31.0	+3.7	60	29	42	−7	1	20	33	24	16	61	0.06	−0.4	1	5,740	w.	28	nw.	4	26	4	1	1.2	0.6	0.0
Wichita	1,358	139	158	28.67	30.16	+.03	32.4	+2.7	63	29	41	−12	3	24	31	29	26	83	T.	−0.8	0	7,953	sw.	42	sw.	24	24	5	2	1.9	T.	0.0
Altus	1,410	5	....	......	......	......	40.0	......	69	24	52	8	1	28	36	....	....	....	0.25	......	3	......	n.	....	......	....	25	0	6	....	0.0	0.0
Muskogee	652	4	....	......	......	......	39.8	......	66	29	50	3	3	30	34	....	....	....	0.48	......	3	......	se.	....	......	....	20	7	4	....	1.1	0.0
Oklahoma	1,214	10	47	28.86	30.19	+.08	38.4	+3.7	65	31	48	1	3	28	30	33	29	78	0.29	−1.0	4	8,518	s.	28	s.	12	22	8	1	2.4	0.2	0.0
Southern Slope.							**38.2**	**−3.3**										**72**	**0.89**	**+0.2**										**3.9**		
Abilene	1,738	10	52	28.33	30.19	+.10	41.6	−1.0	69	12	51	18	1	32	34	36	31	74	2.96	+2.1	7	6,441	s.	29	ne.	25	13	6	12	5.0	9.0	0.0
Amarillo	3,676	10	49	26.35	30.23	+.17	28.7	−5.2	48	20	38	−8	1	20	30	24	20	77	T.	−0.6	0	6,632	nw.	24	s.	11	24	4	3	2.5	T.	0.0
Del Rio	944	64	71	29.16	30.18	+.12	47.7	−2.5	68	13	57	23	4	38	31	....	....	....	0.58	−0.2	5	6,355	nw.	33	nw.	16	13	10	8	4.6	0.0	0.0
Roswell	3,566	75	85	26.47	30.20	+.16	34.5	−4.7	66	31	48	−2	1	22	43	28	21	64	0.02	−0.5	1	4,148	n.	26	nw.	2	24	5	2	2.1	T.	0.0
Southern Plateau.							**39.2**	**−1.6**										**45**	**0.13**	**−0.6**										**2.1**		
El Paso	3,762	110	133	26.29	30.14	+.13	40.7	−3.4	66	31	53	16	3	28	35	32	21	49	0.08	−0.4	1	6,714	nw.	42	ne.	13	24	5	2	2.1	0.3	0.0
Santa Fe	7,013	57	66	23.25	30.23	+.19	24.4	−4.1	46	10	34	−10	2	14	26	19	14	69	0.12	−0.5	2	5,711	ne.	26	n.	8	21	10	0	2.1	1.7	T.
Flagstaff	6,908	8	57	23.39	30.19	+.14	22.2	−4.5	49	24	36	−21	2	8	49	18	....	....	0.94	......	3	......	e.	34	se.	3	28	0	3	....	5.7	5.0
Phoenix	1,108	76	81	28.92	30.10	+.07	50.8	+0.8	74	24	66	23	2	36	40	39	25	42	0.22	−1.0	1	4,133	e.	29	ne.	28	23	6	2	2.1	0.0	0.0
Yuma	141	9	54	29.94	30.10	+.05	55.0	+0.3	75	23	69	28	1	41	36	42	23	32	0.24	−0.2	1	4,933	n.	28	n.	21	26	3	2	1.3	0.0	0.0
Independence	3,910	11	42	26.11	30.22	+.15	42.0	+1.5	66	22	56	16	1	28	37	31	14	35	0.00	−0.9	0	3,999	nw.	24	nw.	1	19	8	4	2.9	0.0	0.0
Needles	488	4	....	29.61	30.13	......	51.4	......	73	23	64	23	1	39	37	....	....	....	0.18	......	1	......	......	....	......	....	18	3	10	....	....	....
Middle Plateau.							**28.1**	**−0.4**										**65**	**0.16**	**−0.9**										**3.4**		
Reno	4,532	74	81	25.59	30.25	+.12	33.7	+1.2	58	18	46	6	1	21	35	28	20	59	0.42	−1.5	3	3,659	w.	39	w.	23	19	4	8	3.4	3.6	0.0
Tonopah	6,090	12	20	24.15	30.22	......	33.2	......	52	23	40	5	1	26	18	27	19	56	0.10	−0.6	1	6,063	se.	27	nw.	21	23	7	1	2.1	T.	T.
Winnemucca	4,344	18	56	25.77	30.29	+.13	29.2	+0.4	56	23	43	−15	1	16	43	24	20	72	0.10	−0.9	3	5,005	ne.	39	sw.	23	19	0	12	4.2	0.3	0.0
Modena	5,479	10	43	24.73	30.27	+.17	25.6	−1.9	54	17	40	−18	1	11	37	20	13	65	0.32	−0.4	2	5,171	w.	31	nw.	20	20	7	4	2.8	1.3	0.2
Salt Lake City	4,360	163	203	25.78	30.28	+.13	32.0	+3.2	55	19	40	8	1	24	23	26	19	59	T.	−1.4	0	3,490	se.	23	se.	31	13	8	10	4.7	0.1	0.0
Grand Junction	4,602	82	96	25.60	30.36	+.30	19.6	−5.1	45	31	33	−15	2	7	31	15	12	79	0.05	−0.4	1	2,614	se.	17	se.	28	19	9	3	2.9	0.6	0.0
Northern Plateau.							**32.4**	**+3.6**										**71**	**1.19**	**−0.4**										**5.8**		
Baker	3,471	48	53	26.56	30.24	+.08	29.6	+5.7	52	17	38	−5	1	21	27	26	22	73	0.62	−0.7	9	5,901	se.	29	sw.	17	11	7	13	5.1	0.3	T.
Boise	2,739	78	86	27.36	30.31	+.12	32.8	+3.5	59	23	41	0	1	24	29	29	22	0.65	0.85	−1.0	7	3,851	se.	25	w.	23	14	7	10	5.1	0.4	0.0
Lewiston	757	40	48	29.34	30.18	+.02	35.8	+1.3	61	17	45	5	1	27	30	....	....	....	1.27	−0.3	9	2,968	e.	34	nw.	23	8	9	14	6.4	0.8	T.
Pocatello	4,477	60	68	25.62	30.30	+.10	27.4	+2.3	51	19	38	−2	1	17	32	23	19	72	0.19	−0.5	5	6,407	se.	33	sw.	23	13	9	9	4.6	0.3	0.0
Spokane	1,929	101	110	28.04	30.15	+.03	31.8	+5.1	56	22	38	0	1	25	22	29	26	78	2.11	−0.2	11	4,898	s.	40	sw.	23	1	11	19	7.7	3.2	0.0
Walla Walla	991	57	65	29.06	30.17	+.02	36.8	+3.6	63	18	44	9	9	29	28	33	27	69	2.12	+0.1	11	4,428	s.	38	w.	23	11	8	12	5.8	4.0	T.
North Pacific Coast Region.							**42.4**	**+2.4**										**84**	**8.72**	**+2.0**										**7.8**		
North Head	211	11	56	29.80	30.03	−.02	44.8	+3.0	60	8	48	32	6	41	14	43	41	87	9.46	+2.8	18	15,676	se.	88	se.	14	7	2	22	7.4	T.	0.0
North Yakima	1,071	4	....	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	......	....	......	....	....	....	....	....	....	....
Port Angeles	29	8	53	30.03	30.06	......	40.5	......	56	16	45	28	1	35	19	....	....	....	7.09	+1.6	17	4,167	s.	38	sw.	14	1	5	25	8.7	T.	0.0
Seattle	125	215	250	29.94	30.08	+.03	41.4	+2.1	56	13	46	27	4	36	17	40	37	84	7.95	+3.4	16	7,326	se.	52	sw.	23	1	5	25	8.6	0.0	0.0
Tacoma	213	113	120	29.84	30.07	+.03	40.8	+2.7	57	17	46	25	3	35	19	39	37	85	9.81	+4.0	17	4,025	s.	36	sw.	14	0	8	23	8.6	0.0	0.0
Tatoosh Island	86	7	57	29.87	29.97	−.01	44.0	+2.8	60	9	48	36	1	40	17	42	39	83	10.30	−1.9	21	15,939	e.	91	s.	14	3	6	22	8.0	0.1	0.0
Medford	1,425	4	....	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	......	....	......	....	....	....	....	....	....	....
Portland, Oreg.	153	68	106	29.93	30.09	+.01	42.2	+3.1	61	18	48	23	4	37	19	40	36	79	9.08	+2.6	17	5,099	s.	34	w.	23	9	5	17	6.5	0.0	0.0
Roseburg	510	9	57	29.58	30.14	+.04	41.3	+0.5	68	22	48	18	1	35	24	39	36	84	7.33	+1.6	16	2,373	s.	33	sw.	23	4	14	13	6.6	0.0	0.0
Middle Pacific Coast Region.							**48.4**	**+1.1**										**75**	**3.25**	**−1.5**										**4.4**		
Eureka	62	73	89	30.08	30.15	+.05	49.0	+2.1	70	9	55	31	1	43	24	47	44	85	7.84	+0.2	17	5,536	se.	43	sw.	15	9	6	16	6.4	0.0	0.0
Mount Tamalpais	2,375	11	18	27.66	30.17	+.08	46.3	+0.4	62	28	52	30	31	41	22	40	32	66	3.54	−2.4	10	13,448	nw.	62	s.	19	14	8	9	4.5	0.0	0.0
Point Reyes Light	490	7	18	29.59	30.11	......	51.5	+2.1	68	8	56	40	1	47	21	....	....	....	2.78	......	11	12,808	se.	80	nw.	31	15	6	10	4.6	0.0	0.0
Red Bluff	332	50	56	29.81	30.18	+.06	47.0	+1.6	70	4	57	21	1	37	40	42	36	70	2.74	−1.2	8	4,162	nw.	27	n.	31	14	4	13	4.7	0.0	0.0
Sacramento	69	106	117	30.12	30.19	+.07	46.2	+0.6	60	27	55	24	1	37	28	44	40	80	1.77	−1.9	7	4,331	se.	24	sw.	19	17	5	9	4.1	0.0	0.0
San Francisco	155	209	213	30.00	30.17	+.06	51.2	+1.7	63	29	58	37	1	44	18	47	42	73	2.57	−1.8	7	3,925	n.	26	sw.	20	19	3	9	3.6	0.0	0.0
San Jose	141	12	110	30.02	30.17	......	47.6	−0.7	67	27	61	22	1	34	37	....	....	....	1.06	−1.8	4	3,668	se.	24	se.	19	21	3	5	2.8	0.0	0.0
South Pacific Coast Region.							**54.6**	**+3.8**										**58**	**0.87**	**−1.9**										**3.0**		
Fresno	327	89	98	29.83	30.20	+.10	48.2	+2.8	66	15	60	26	1	37	34	42	36	66	0.40	−1.2	5	3,443	nw.	23	nw.	25	19	8	4	2.8	0.0	0.0
Los Angeles	338	159	191	29.79	30.09	+.01	60.2	+7.1	79	24	71	36	2	50	34	48	35	46	0.96	−1.9	4	4,503	ne.	28	nw.	25	19	5	7	3.2	0.0	0.0
San Diego	87	62	70	29.98	30.08	+.01	56.6	+2.6	77	9	66	35	1	47	30	48	40	60	0.61	−1.4	3	3,371	nw.	25	w.	31	20	6	5	2.8	0.0	0.0
San Luis Obispo	201	32	40	29.93	30.15	+.06	53.6	+2.6	78	28	67	27	2	40	45	45	36	59	1.51	−3.2	6	2,770	n.	22	ne.	13	19	6	6	3.4	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.91	30.00	−.02	74.6	......	85	9	80	64	3	69	17	....	....	....	1.87	−2.8	17	7,284	se.	40	ne.	1	21	7	3	3.3	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.72	29.84	−.02	79.8	−0.3	90	2	88	70	6	72	19	72	71	78	0.28	−0.7	7	8,573	n.	32	nw.	10	8	22	1	4.5	....	....
Colon	36	30	97	29.82	29.86	−.02	79.6	0.0	84	8	82	74	12	77	9	75	73	80	1.82	−2.0	20	11,359	n.	32	n.	12	3	20	8	5.8	....	....
Alaska.																																
Juneau	80	11	49	......	......	......	32.0	......	46	10	36	14	19	28	12	30	27	82	11.41	......	26	3,999	se.	23	se.	13	5	2	24	8.1	26.5	10.6

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during January, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	21-22			1.36														0.23			
Albany, N. Y	23			0.47														0.17			
Alpena, Mich	7			0.20														*			
Anniston, Ala	23			1.05														0.28			
Asheville, N. C	23			1.05														0.27			
Atlanta, Ga	17			1.55														0.29			
Atlantic City, N. J	23			1.85														0.64			
Augusta, Ga	17			1.50														0.28			
Baker, Oreg	21-22			0.26														*			
Baltimore, Md	23			1.04														0.24			
Bentonville, Ark	14			0.22														0.07			
Binghamton, N. Y	1			0.38														0.09			
Birmingham, Ala	23			1.12														0.34			
Bismarck, N. Dak	3-4			0.05														*			
Block Island, R. I	23-24			0.98														0.39			
Boise, Idaho	21			0.42														0.09			
Boston, Mass	24			1.15														0.57			
Buffalo, N. Y	3			0.38														*			
Burlington, Vt	23-24			0.51														*			
Cairo, Ill	22			0.39														0.16			
Canton, N. Y	8-9			0.29														*			
Charles City, Iowa	1			0.15														*			
Charleston, S. C	8			0.41														0.13			
Charlotte, N. C	23			1.20														0.31			
Chattanooga, Tenn	23			0.91														0.35			
Cheyenne, Wyo	27			T.														T.			
Chicago, Ill	5-6			0.14														*			
Cincinnati, Ohio	1			0.80														0.29			
Cleveland, Ohio	1			0.27														*			
Columbia, Mo	4			0.07														*			
Columbia, S. C	25			1.19														0.35			
Columbus, Ohio	1			0.71														*			
Concord, N. H	23-24			1.80														*			
Concordia, Kans	3-4			0.02														*			
Corpus Christi, Tex	7			1.20														0.66			
Dallas, Tex	22			0.27														0.22			
Davenport, Iowa	1			0.01														*			
Dayton, Ohio	1			0.50														0.19			
Del Rio, Tex	21			0.16														0.15			
Denver, Colo	13			0.12														*			
Des Moines, Iowa	4-5			0.02														*			
Detroit, Mich	23			0.54														*			
Devils Lake, N. Dak	6			0.15														*			
Dodge City, Kans	13			0.06														*			
Drexel, Nebr	3-4			0.12														*			
Dubuque, Iowa	1			0.11														*			
Duluth, Minn	22			0.27														*			
Eastport, Me	3			0.86														*			
Elkins, W. Va	1			1.47														0.18			
Ellendale, N. Dak	3-4			0.05														*			
El Paso, Tex	14			0.08														*			
Erie, Pa	1			0.38														*			
Escanaba, Mich	1			0.15														*			
Eureka, Cali	17			1.52														0.37			
Evansville, Ind	1			0.41														0.12			
Flagstaff, Ariz	31			0.87														*			
Fort Smith, Ark	22			0.48														0.28			
Fort Wayne, Ind	22-23			0.55														*			
Fort Worth, Tex	22			0.86														0.56			
Fresno, Cali	19			0.34														0.19			
Galveston, Tex	15-16	6:05 p. m.	7:30 a. m.	2.26	9.30 p. m.	10:31 p. m.	0.26	0.09	0.15	0.27	0.48	0.56	0.63	0.70	0.75	0.79	0.86	0.98			
Grand Haven, Mich	1			0.39														*			
Grand Junction, Colo	12			0.05														*			
Grand Rapids, Mich	25			0.04														0.04			
Green Bay, Wis	1			0.26														*			
Greenville, S. C	23			1.75														0.44			
Hannibal, Mo	5			0.02														*			
Harrisburg, Pa	2-3			1.08														*			
Hartford, Conn	23-24			0.70														0.18			
Hatteras, N. C	17			1.26														0.41			
Havre, Mont	11			0.18														*			
Helena, Mont	23			0.05														*			
Houghton, Mich	1-2			0.35														*			
Houston, Tex	22	6:45 a. m.	4:25 p. m.	1.87	8:37 a. m.	9:27 a. m.	0.18	0.09	0.24	0.34	0.37	0.40	0.46	0.60	0.72	0.83	0.96				
Huron, S. Dak	3-4			0.11														*			
Independence, Cal																					
Indianapolis, Ind	23			0.61														0.15			
Iola, Kans	4			0.02														*			
Jacksonville, Fla	17			0.52														0.38			
Kalispell, Mont	20			0.34														*			
Kansas City, Mo	4			0.07														*			
Keokuk, Iowa	5			0.01														*			
Key West, Fla	17			0.31														0.30			
Knoxville, Tenn	1			1.91														0.26			
La Crosse, Wis	7			0.12														*			
Lander, Wyo																					
Lansing, Mich	22-23			0.19														*			
Lewiston, Idaho	22			0.41														0.17			
Lexington, Ky	1			1.37														0.23			
Lincoln, Nebr	3			0.03														*			
Little Rock, Ark	22			0.69														0.16			
Los Angeles, Cal	31			0.84														0.28			
Louisville, Ky	23			0.83														0.17			
Ludington, Mich	2			0.24														*			
Lynchburg, Va	2			1.80														0.20			
Macon, Ga	25			1.45														0.31			
Madison, Wis	1			0.18														*			
Marquette, Mich	3			0.56														*			
Memphis, Tenn	17			0.97														0.17			
Meridian, Miss	2			1.87														0.22			

* Self register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during January, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Miami, Fla	17			0.32														0.30			
Milwaukee, Wis	1			0.12														*			
Minneapolis, Minn	6-7			0.17														*			
Mobile, Ala	16-17	4:45 p. m.	D.N.A.M.	1.61	8:58 p. m.	9:23 p. m.	0.50	0.21	0.37	0.55	0.66	0.73									
Modena, Utah	31			0.30														*			
Montgomery, Ala	25			1.96														0.49			
Moorhead, Minn	6			0.08														*			
Mount Tamalpais, Cal	19			1.90														0.28			
Nantucket, Mass	3			1.79														0.23			
Nashville, Tenn	1			3.01														0.56			
New Haven, Conn	23-24			0.80														0.23			
New Orleans, La	25			2.20														0.53			
New York, N. Y	23			1.26														0.28			
Norfolk, Va	26			0.73														0.25			
Northfield, Vt	23-24			0.47														*			
North Head, Wash	22			2.41														0.34			
North Platte, Nebr	1			0.02														*			
Oklahoma, Okla	26			0.12														0.08			
Omaha, Nebr	3-4			0.10														*			
Oswego, N. Y	23			0.34														*			
Palestine	22			0.32														0.23			
Parkersburg, W. Va	1			1.43														0.27			
Pensacola, Fla	25	4:10 a. m.	1:10 p. m.	2.29	11:18 a. m.	12 noon	1.22	0.06	0.21	0.35	0.37	0.52	0.65	0.79	0.89	0.93					
Peoria, Ill	22			0.03														0.02			
Philadelphia, Pa	23			1.17														0.24			
Phoenix, Ariz	31			0.22														0.06			
Pierre, S. Dak	3			0.04														*			
Pittsburgh, Pa	23			0.41														0.16			
Pocatello, Idaho	23			0.13														0.13			
Point Reyes Light, Cal	19			1.32														0.28			
Port Angeles, Wash	16			0.62														0.30			
Port Huron, Mich	23			0.54														*			
Portland, Me	24			2.06														0.54			
Portland, Oreg	18			1.50														0.25			
Providence, R. I	23-24	9:00 p. m.	6:10 a. m.	2.05	1:21 a. m.	2:16 a. m.	0.96	0.07	0.13	0.19	0.29	0.38	0.49	0.57	0.72	0.81	0.89				
Pueblo, Colo	13			0.03														*			
Raleigh, N. C	26			0.92														0.30			
Rapid City, S. Dak	3			0.04														*			
Reading, Pa	23			1.04														0.23			
Red Bluff, Cal	19			1.30														0.26			
Reno, Nev	19-20			0.27														*			
Richmond, Va	23			0.38														0.22			
Rochester, N. Y	3			0.33														*			
Roseburg, Oreg	17			1.30														0.28			
Roswell, N. Mex	14			0.02														*			
Sacramento, Cal	20			0.49														0.38			
Saginaw, Mich	23			0.16														0.04			
St. Joseph, Mo	4			0.03														*			
St. Louis, Mo	22-23			0.07														*			
St. Paul, Minn	6-7			0.15														*			
Salt Lake City, Utah	1			T														*			
San Antonio, Tex	21	1:45 p. m.	9:32 p. m.	1.44	7:55 p. m.	8:24 p. m.	0.76	0.10	0.27	0.39	0.47	0.52	0.58								
San Diego, Cal	31			0.46														0.32			
Sandusky, Ohio	23			0.42														0.20			
Sandy Hook, N. J	23			1.26														0.29			
San Francisco, Cal	19			1.57														0.30			
San Jose, Calif	19			0.66														0.23			
San Luis Obispo, Cal	20			0.73														0.36			
Santa Fe, N. Mex	12			0.08														*			
Sault Ste. Marie, Mich	1			0.23														*			
Savannah, Ga	8			0.54														0.17			
Scranton, Pa	23			0.60														0.08			
Seattle, Wash	18			1.46														0.22			
Sheridan, Wyo	2			0.25														*			
Shreveport, La	7			0.43														0.31			
Sioux City, Iowa	3-4			0.24														*			
Spokane, Wash	10-11			0.58														*			
Springfield, Ill	5			0.05														*			
Springfield, Mo	4-5			0.19														*			
Syracuse, N. Y	2-3			0.51														*			
Tacoma, Wash	18			2.05														0.40			
Tampa, Fla	8			1.71														0.35			
Tatoosh Island, Wash	17			1.28														0.33			
Taylor, Tex	15-16			1.32														*			
Terre Haute, Ind	22			0.56														0.24			
Thomasville, Ga	2			1.10														0.24			
Toledo, Ohio	23			0.50														*			
Tonopah, Nev	31			0.10														*			
Topeka, Kans	4			0.06														*			
Trenton, N. J	23			1.20														0.36			
Valentine, Nebr	3-4			0.04														*			
Vicksburg, Miss	1			1.52														0.31			
Walla Walla, Wash	19-20			0.70														*			
Washington, D. C	23			0.91														0.31			
Wausau, Wis	7			0.12														*			
Wichita, Kans	4			T														*			
Williston, N. Dak	1			0.04														*			
Wilmington, N. C	17			1.47														0.66			
Winnemucca, Nev	17			0.04														0.03			
Wytheville, Va	1			0.48														0.17			
Yankton, S. Dak	3-4			0.14														*			
Yellowstone Park, Wyo	23			0.18														*			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian Meteorological Service, January, 1919.*

Stations.	Altitude above M. S. L.[1] Jan. 1, 1916.	Pressure: Station reduced to mean of 24 hours.	Pressure: Sea level reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature: Mean max. + mean min. ÷ 2.	Temperature: Departure from normal.	Temperature: Mean maximum.	Temperature: Mean minimum.	Temperature: Highest.	Temperature: Lowest.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N.F.	125	29.59	29.73	−0.13	25.9	+ 2.1	32.6	19.2	58	0	6.16	+0.25	13.0
Sydney, C. B. I.	48	29.82	29.86	− .07	26.4	+ 5.9	33.4	19.3	50	− 5	4.70	−0.40	13.0
Halifax, N. S.	88	29.78	29.88	− .09	27.3	+ 5.5	34.9	19.7	49	− 6	5.06	−0.71	5.8
Yarmouth, N. S.	65	29.81	29.88	− .12	30.3	+ 4.0	37.0	23.6	50	1	5.03	−0.38	6.1
Charlottetown, P. E. I.	38	29.82	29.86	− .10	22.2	+ 5.2	28.5	15.8	44	−12	2.72	−1.24	11.2
Chatham, N. B.	28	29.87	29.90	− .07	15.7	+ 5.9	24.5	6.9	39	−17	3.27	−0.32	31.5
Father Point, Que.	20	29.91	29.94	− .04	10.8	+ 2.8	19.6	2.1	34	−17	4.74	+1.89	45.4
Quebec, Que.	296	29.61	29.95	− .07	13.8	+ 4.7	20.4	7.1	36	−20	3.44	−0.57	33.4
Montreal, Que.	187	29.75	29.97	− .07	18.3	+ 6.6	26.3	10.4	40	−15	2.69	−1.04	16.8
Stonecliffe, Ont.	489	....	....	....	....	....	....	....	....	....	....	....	....
Ottawa, Ont.	236	29.71	29.99	− .04	18.1	+ 8.5	27.8	8.5	40	−20	2.68	−0.31	19.3
Kingston, Ont.	285	29.68	30.01	− .04	25.0	+ 7.9	33.0	17.0	46	−12	1.92	−1.53	11.7
Toronto, Ont.	379	29.58	30.01	− .04	29.3	+ 7.9	36.6	22.0	47	0	1.03	−1.89	4.3
White River, Ont.	1,244	28.54	29.91	− .10	8.5	+ 8.9	20.0	−3.6	35	−37	1.47	−0.22	14.7
Port Stanley, Ont.	592	29.37	30.03	− .04	29.2	+ 7.0	35.7	22.7	47	5	1.49	−1.50	4.9
Southampton, Ont.	656	29.23	....	....	27.1	+ 6.7	33.7	20.5	46	− 1	3.16	−0.89	21.0
Parry Sound, Ont.	688	29.24	29.97	− .04	22.9	+ 9.1	31.5	14.3	39	−20	3.58	−0.50	33.0
Port Arthur, Ont.	644	29.23	29.96	− .11	16.7	+13.6	26.2	7.2	38	−22	0.26	−0.56	2.6
Winnipeg, Man.	760	29.08	29.95	− .16	11.0	+17.8	19.1	2.9	37	−29	0.18	−0.70	1.8
Minnedosa, Man.	1,690	28.05	29.96	− .14	9.5	+16.7	19.6	−0.6	38	−35	0.74	−0.06	7.4
Qu'Appelle, Sask.	2,115	27.57	29.90	− .18	17.7	+21.5	27.8	7.6	43	−33	0.70	+0.20	6.6
Medicine Hat, Alberta	2,144	27.54	29.86	− .21	32.0	+26.5	42.0	22.0	58	−15	0.02	−0.55	....
Swift Current, Sask.	2,392	27.24	29.88	− .21	25.5	+22.4	34.7	16.3	51	−25	0.50	−0.14	5.0
Calgary, Alberta	3,428	26.26	29.86	− .17	31.0	+22.6	42.0	20.0	55	6	0.34	−0.19	3.4
Banff, Alberta	4,521	2[illegible].25	29.97	− .03	23.6	+11.5	31.3	15.8	42	−14	2.07	+0.88	20.7
Edmonton, Alberta	2,150	27.47	29.81	− .22	21.8	+20.0	31.9	11.7	47	−15	1.08	+0.40	10.6
Prince Albert, Sask.	1,450	28.27	29.90	− .19	12.7	+21.1	22.1	3.2	45	−35	0.93	−0.04	9.3
Battleford, Sask.	1,592	28.07	29.87	− .21	15.6	+21.5	27.0	4.2	45	−27	0.74	+0.34	7.4
Kamloops, B. C.	1,262	28.78	30.11	+ .15	30.5	+ 7.5	35.6	25.3	47	5	0.32	−0.50	0.7
Victoria, B. C.	230	29.76	30.02	+ .05	41.3	+ 2.8	45.0	37.6	52	33	5.81	+0.42	....
Barkerville, B. C.	4,180	25.52	29.89	.00	23.8	+ 6.0	30.1	17.5	38	0	2.30	−0.30	23.0
Hamilton, Bermuda	151	29.95	30.12	− .01	63.7	+ 1.7	68.7	58.8	71	51	6.56	+1.62	....

SEISMOLOGICAL TABLES.

SEISMOLOGICAL REPORTS FOR JANUARY, 1919.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Seismological Investigations, Weather Bureau, March 3, 1919]

SEISMOLOGICAL ABBREVIATIONS USED IN THE INSTRUMENTAL REPORTS.

CHARACTER OF THE EARTHQUAKE.

I=noticeable.
II=conspicuous.
III=strong.
d=(terræ motus domesticus)=local earthquake (sensible or felt).
v=(terræ motus vicinus)=near-by earthquake (within 1,000 km.).
r=(terræ motus remotus)=distant earthquake (1,000 to 5,000 km. distant).
u=(terræ motus ultimus)=very distant earthquake (beyond 5,000 km.).
$\triangle$=distance to epicenter.

PHASES.

P=(undæ primæ)=first preliminary tremors.
PR_n=P waves reflected n times at the earth's surface.
S=(undæ secundæ)=second preliminary tremors.
SR_n=S waves reflected n times at the earth's surface.
PS=transformed waves; longitudinal (P) to transversal (S) or vice versa.
L=(undæ longæ)=long waves in the principal portion.
M=(undæ maximæ)=greatest motion in the principal portion.
C=(coda)=trailers.
O=time at epicenter.
L_{rep_1}=long waves reaching the station from the antiepicenter (40,000 km. $-\triangle$).
L_{rep_2}=long waves again reaching the station from the antiepicenter (40,000 km.$+\triangle$).
F=(finis)=end of perceptible trace.

NATURE OF THE MOTION.

i=(impetus)=abrupt beginning.
e=(emersio)=gradual appearance.
T=period=twice time of oscillation.
A=amplitude of earth's movement, reckoned from the zero line.
E, N, or Z attached to a symbol signifies the E-W, the N-S, or the vertical component, respectively, thus:
P_E is the E-W component of P.
P_N is the N-S component of P.
P_Z is the vertical component of P.
μ=micron, $\frac{1}{1,000}$ mm.

INSTRUMENTAL CONSTANTS.

T_0=period of instrument.
V=magnification of instrument.
ϵ=damping ratio.

TABLE I.—*Noninstrumental earthquake reports, January, 1919.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity, Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
	m. m.		° ′	° ′			*Sec.*			
Jan. 8	4 07	Hemet	33 45	116 45	2	1	2	Rumbling		C. E. McManigal.
20	9 30	Napa	38 18	122 20	5	1	5	Faint	Awakened people	Geo. A. Lewis.
		St. Helena	38 41	122 30	4	1		None		F. B. Mackinder.
		Vallejo	38 07	122 18	4	1		None	Shock distinct	Press report.
25	22 29	Bakersfield	35 32	119 00	3-4	3			Like heavy trucks passing	F. W. Warthorst.
		Maricopa	35 05	119 23	3	1		None.		E. F. Foulke.
		Ojai	34 25	119 12	5	1	1	None		Wm H. Duncan

TABLE 2.—*Instrumental seismological reports, January, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see this REVIEW, p. 59.]

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(Report for January, 1919, not received.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: $\begin{cases} & V & T_0 \\ E & 10 & 17.7 \\ N & 10 & 16.6 \end{cases}$

Date.	Character.	Phase.	Time.	Period. T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		P_N	3 12 01	2				Phases marked doubtful are in each case single large irregular waves of 0.5 to 1.0 mm. amplitude.
		P_E	3 12 12	4				
		S_N?	3 22 34					
		S_E?	3 22 37					
		M_E	3 22 48		100			
		e_N?	3 28 14					
		e_E?	3 28 18					
		M_N	3 28 24			90		
		e_E?	3 34 52					
		e_N?	3 34 54					
		F_E	3 44 ..					
		F_N	3 47 ..					

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. William H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch Omori, 10 and 12 kg.

Instrumental constants: $\begin{cases} & V & T_0 \\ E & 10 & 13.8 \\ N & 10 & 18.4 \end{cases}$

Date.	Character.	Phase.	Time.	Period. T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		P_N	3 12 28					E-W out of order. No well-defined long waves.
		iS_N	3 22 20					
		M_N	3 22 30			1,400		
		F_N	4 22 ..					
17		eP_N	11 54 17	5				
		eP_E	11 54 28	6				
		eS_N	11 58 29	6				
		eS_E	11 58 40	6				
		L_N	12 00 19	14				
		L_E	12 00 28	16				
		M_N	12 01 39	9		180		
		M_E	12 01 48	10	680			
		C_E	12 03 ..	9				
		C_N	12 04 ..	9				
		F_N	12 08 ..					
		F_E	12 26 ..					
31		e_E	23 51 55	12				
		e_N	23 52 29	12				
		M_N	23 52 45			10		
		M_E	23 54 ..		20			
Feb. 1		F_E	0 01 ..					
		F_N	0 03 ..					

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period. T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 6					*50	*100		Tremors during 24 hours preceding 16h 00m on date given.

* Amplitude on instrument.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See Record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

(No earthquake recorded during January, 1919.)

District of Columbia. *Washington, U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants.. $\begin{cases} V & T_0 \\ 110 & 6.4 \end{cases}$

Date.	Character.	Phase.	Time.	Period. T.	A_E	A_N	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	*km*	
Jan. 1		eP	1 52 55?				1,860?	
		eS	1 56 06					
		eL?	2 07 00					
		L	2 40 30	28				
		L	2 55 00	20				F lost in next quake.
1		P	3 17 44				5,300?	
		S	3 24 42					
		L	3 28 40					
		L	3 31 60	28				
		L	3 39 30	18				
		F	5 40 ..					
6		eL	23 30 30	18				On E-W only.
		F	23 40 00					
8		eL	2 01 00					Not on N-S.
		F	2 07 00					
17		e	11 55 45					
		S	12 01 07					
		eL?	12 13 19					
		F	12 30 00					
31		e	23 59 30					
Feb. 1		eL	0 02 50					
		F	0 20 00					

TABLE 2.—*Instrumental seismological reports, January, 1919*—Continued.

District of Columbia. *Washington. Georgetown University.*

F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants	V	T_0	ε
E	165	5.4	0
N	143	5.2	0
Z	80	5.0	0

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	km	
Jan. 1		eP_N	1 56 18					Microseisms. No distinct main.
		eP_E	1 56 19					
		eL?	2 25 06					
		L_N	2 33 00	17				
		L_E	2 33 19	17				F in next quake.
1		eP_E	3 17 57					
		eP_N	3 18 17					
		S_E	3 24 37					
		i_N	3 26 39					
		eL_E	3 28 24					
		eL_N	3 28 42					
		i_E	3 30 20					
		i_N	3 34 20					
		i_N	3 38 30					
		F	5 46 ..					
5		e	20 03 00					Little value can be set on these data because of local disturbances.
		S?	20 10 11					
		F	20 35 ..					
8		e_E	1 58 17					Scarcely visible on N-S.
		eL_E	2 01 ..					
		F	2 09 ..					
17		eP_E	11 53 41					Heavy microseisms F difficult.
		eP_N	11 54 00					
		S_E	12 01 07					
		S_N	12 01 08					
		L_E	12 16 55	11				
		L_N	12 17 55	11				
		F?	12 50 ..					
			VERTICAL.					
		eP_Z	*11 53 46*					
		L_Z	*12 18 12*	*10*				
		F_Z	*12 43 ..*					
27		e_E	21 59 11					
		i_E	21 59 25					
		eL_E?	22 16 54					F?.
31		e_N	23 58 22					Microseisms.
Feb. 1		eL	0 03 30					
		L_E	0 05 43	11				
		L_N	0 07 25	11				
		F	0 20 ..					

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 18.6

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	km	
Jan. 1		P	1 45 24	19				
		S	1 55 12	17				
		L	2 08 18	22				
		M	2 22 18	18	*6,300			
		C	2 42 ..	19				F in next quake.
1		e	3 07 36	10				Waves of amplitude greater than the width of the record began abruptly at 3h 14m30s.
		L	3 14 30	20				
		M	3 15 00	20	*17,000			
		C	3 28 ..	18				
		F	7 18 ..					
5		eP	20 17 24	18				
		L	20 38 00	23				
		M	20 44 00	19	*400			
		C	20 47 ..	18				
		F	21 12 ..					
6		P	22 32 42	16				
		S	22 40 00	20				
		eL	22 46 54	20				
		M	22 55 00	18	*4,000			
		C	22 58 ..	18				
		F	25 30 ..					

Hawaii. *Honolulu*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	km.	
Jan. 7		eL	12 41 06					
		M	12 47 48	18	*100			
		F	12 53 ..					
8		eL	2 37 00					
		M	2 43 12	18	*100			
		F	2 47 ..					
8		eL	6 54 00					
		M	6 58 48	21	*100			
		F	7 06 ..					
8		eL	22 11 06					
		M	22 15 30	18	*100			
		F	22 22 30					
11		eL	10 00 54	20				
		M	10 10 12	18	*200			
		F	10 31 ..					
17		eL	12 17 30	20				
		M	12 21 00	18	*200			
		F	12 25 ..					
27		eL	21 53 00	21				
		M	21 53 24		*200			
		F	22 42 ..					
29		L	3 23 00					Local shock, felt in the islands. Principal portion a mere haze (on account of the rapid motion) similar to record of a quake on a magnetograph.
		M	3 23 18		*200			
		C	3 23 48					
		F	3 29 ..					
31		eL	23 55 42	20				
Feb. 1		M	0 02 30	21	*200			
		F	0 14 ..					

* Trace amplitude.

Kansas. *Lawrence. University of Kansas.* Department of Physics and astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters. Instrument: Wiechert.

Instrumental constants	V	T_0	ε
E	177	3.4	4:1
N	205	3.4	4:1

(Report for January, 1919, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters. Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants	V	T_0
E	10	15
N	10	15

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	km.	
Jan. 1		eP_N	1 56 55					
		eP_E	1 56 59					
		eL_E	2 37 40					
		eL_N	2 37 45					
		M_N	2 56 55	20		20		
		M_E	2 57 30	20	10			F in next quake.
1		P_E	3 19 20	3				Record not clear, phases not well defined.
		P_N	3 19 53	3				
		eS_E	3 25 12					
		iS_N	3 26 59			400		
		eL_E	3 29 09					
		M_N	3 34 54	18		460		
		M_E	3 35 19	14	250			
		eL_N	3 39 40					
		C_N	3 58 —					
		C_E	4 17 —					
		F_N	4 48 —					
		F_E	5 10 —					
17		eP_E	12 01 09	10				Phases obscured by microseisms.
		eP_N	12 01 17	9				
		M_N	12 09 30	8		10		
		M_E	12 09 34	10	20			
		F_E	12 31 —					
		F_N	12 33 —					

TABLE 2.—*Instrumental seismological reports, January, 1919*—Continued.

Massachusetts. *Cambridge. Harvard University Seismographic Station,* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.. E: V 80, T_0 23, ϵ 0; N: V 50, T_0 25, ϵ 4:1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Jan. 1		S_E?	1 53 51	10			16,000?	
		e_E?	2 19 42	20				
		eL_E	2 25 05	35				
		L	2 32 23	26				
		M	2 36 55	20				
		M	2 41 16 2 45 ..	24				
		C	3 08 ..	15				F in next record.
1		*O*	*3 11 43*				5,200	46° 48′ of arc.
		eP_N	3 20 24					
		eP_E	3 20 30	4				
		PR_N	3 20 56					
		PR_E	3 20 57					
		e_E	3 22 34	8				
		S_E	3 27 17	12				
		S_N	3 27 41	9				
		SR_N	3 30 59					Sn, undamped, followed by extraordinary large waves like MM up to 72 mm. Trace undamped.
		eL_E	3 34 28	20				
		M_N	3 36 ..		*66,000			
		M_N	3 40 ..					
		M_N	3 43 ..					
		M_N	3 48 ..					
		M_N	3 54 ..					
		C_N	3 56 ..					
		L_N	4 05 ..					A beautiful lenticular group of sinusoidal waves. Not L_{rep} waves. Must be S waves coming back from anticentrum.
		M_E	4 07 ..					
		M_E	4 11 ..					
		F_N	7 01 44					
4								Several disturbances on N-S between 10ʰ 44ᵐ and 13h; possibly local temperature effects. Microseisms only on E-W.
6		*O*?	*23 04 15*				4,980?	Time somewhat uncertain.
		S_E?	23 19 43	8				
		L_E?	23 26 27					
		L_E	23 30 51	20				
7		L_N	0 20 49	24				Possibly part of preceding, but shown best on N-S while preceding quake is most legible on E-W.
		L_N	0 27 20	24				
		L_N	0 45 29	16				
		F	0 51 ..					
8		*O*?	*1 43 28*					Powder explosion at Acton, Mass., 26.8 km. away, bearing N. 75° W. Temperature about 0° C. Record superposed on L of preceding. SL probably forced ground wave traveling under sound wave around 333 m. per sec. No check on time at origin obtainable.
		e_N	1 59 49					
		SL	1 59 54	0.3				
		M_N	1 59 57	0.3	5			
		M_N	1 59 59	0.3	5			
		M_E	1 59 58	0.3	5			
		C_E	2 00 03					
		C_N	2 00 07					
		F_N	2 00 23					
		F_E	2 00 24					
9		e	11 51 38					
		e_E	11 56 48	3				
		e_E	11 56 49	10				
		S_E?	12 02 20	15				
		S_E?	12 02 33	13				
		L_E	12 11 41	12				
		L_E	12 17 ..	8				
		C_E	13 38 20					
		F	12 55 ..					

Massachusetts. *Cambridge*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Jan. 17		e?	11 51 37					Some disturbance also from 8ʰ onward.
		e_E	11 56 55	3				
		e_E	11 57 58	10				
		S_E?	12 02 29	15				
		S_E?	12 02 42	13				
		L_E?	12 11 50	12				
		L_N	12 15 .. 12 35 ..					
		C_E	12 38 ..					
		F_E	12 55 31					
18		L_N	9 20 52					Earlier phases masked by microseisms. Not recognizable on E-W.
		L_N	9 23 41	20				
		L_N	9 28 22	15				
		F	9 29 35					

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants.. V 80, T_0 7, ϵ 5:1

(Report for January, 1919, not received.)

New York. *Fordham. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 29.3 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants.. E: V 72, T_0 5.0, ϵ 0; N: V 72, T_0 5.0, ϵ 0

(Report for January, 1919, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants.. E: V 13, T_0 22, ϵ 4:1; N: V 14, T_0 25, ϵ 4:1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Jan. 1		e_N?	1 56 16	5				
		e_E?	1 56 17	4				
		e_N	2 04 45	9				
		e_E	2 06 20	10				
		e_E	2 11 40	7				
		e_N	2 12 05	10				
		e_N	2 22 10	14				
		L_E	2 30 02	44				
		L_E	2 38 30	27				F in next 'quake.
1		eP_N	3 18 50	3				
		eP_E	3 19 20	5				
		e_N	3 22 05	4				
		e_E	3 24 45	8				
		e_E	3 27 45	18				
		L_E	3 37 ..	24				
		F_E	5 51 ..					
17		eP	11 56 50	5				
		S_E	12 01 36	11				
		S_N	12 01 40	13				
		eL	12 10 ..	10				
		F	12 51 ..					

TABLE 2.—*Instrumental seismological report, January, 1919*—Continued.

Panama Canal. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori: 100 kg.

Instrumental constants.. V 35, T_0 20

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		P	1 53 00					Distance and direction uncertain.
		F	1 59 00					
1		P	3 16 00		*1,500	*1,600		Distance and direction uncertain.
		F	4 20 00					

* Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wallace M. Hill.

Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.. E: V 10, T_0 17; N: V 10, T_0 20

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		P_E	3 19 15	6				Waves of irregular period and amplitude; apparently overlapping waves of different periods, a larger wave showing occasionally when the phases coincide.
		P_N	3 19 18	3				
		eS_E	3 29 19	10				
		M_E	3 30 05	20	200			
		eS_N	3 30 06	18				
		L_E	3 35 35	20				
		L_N	3 35 36	18				
		M_N	3 35 52	18		190		
		C_N	3 37 ..	16				
		C_E	3 40 ..	16				
		F_N	4 19 ..					
		F_E	4 30 ..					

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants.. E: V 10, T_0 15; N: V 10, T_0 16

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		eL_E	2 40 00	24				
		L_E	2 58 30	20				
		F	3 10 00					
1		e	3 19 30					
		S_E?	3 26 54					
		L	3 28 50	22				
		L	4 05 30	14				
		F	5 00 00					

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80k. vertical seismograph.

Instrumental constants.. V 120, T_0 26

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		i_N	1 54 27	9				The source lay nearer to Ottowa than Halifax and was probably at least 1,500 km. away from the former. F lost in next 'quake.
		e_N	2 03 44	12				
		eL?	2 26 ..	60				
		L	2 36 ..	30				
		L	2 40 ..	26				
1		*O?*	*3 12 55*				3,200?	Record very confusing, especially due to fact that that the i records on N-S were not recorded on E-W and regular phases appearing on latter were not visible on former. Same phenomenon present on Halifax record.
		eP_E?	3 19 10					
		eS_E?	3 24 08					
		i_N	3 26 37					
		eL_E?	3 28 30					
		i_N	3 29 24					
		i_N	3 34 38					
		i_N	3 38 40					
		L	3 40 ..	30				
		L	3 50 ..	30				
		L	4 05 ..	18				
		L_N	4 10 ..	44				
		L	4 20 ..	14				
		L	4 35 ..	14				
		L_N	4 45 ..	40				
		L_N	5 15 ..	35				
		F	6					
5		i	20 13 07	8				
		eL	20 35 ..	19				
		F	20 50 ..					
6		eL	{23 26 .. / 23 40 ..}	19				Heavy microseisms.
		L	23 50 ..	17				
7		L	0 05 ..	15				
		F	0 20 ..					
8		e	1 58 18					Heavy microseisms.
		eL	2 01 ..	19				
		F	2 20 ..					
17		*O?*	*11 49 44*				3,840?	Short, choppy irregular L waves, the beginning of which can not be accurately determined.
		iP?	11 56 50					
		e_N?	12 02 05					
		eS?	12 02 28					
		eL	?	10				
		L	12 16 ..	8				
		L	12 23 ..	7				
		L_N	12 34 ..					
		F	13					
18		eL	{7 12 .. / 7 30 ..}					Barely discernible; heavy microseisms.
27		e	22 03 30					Irregular. Heavy microseisms.
		eL	22 09 ..					
		L	{22 11 .. / 22 25 ..}					
		F	22 40 ..					

TABLE 2.—*Instrumental seismological reports, January, 1919*—Continued.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant..18 T_0. Pillar deviation, 1 mm. swing of boom—0.45″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		e	2 03 42					Early phases masked by microseisms.
		eL	2 10 06					
		L	2 36 48					
		L	2 53 42					
		M	2 56 06		*1,000			F lost in next 'quake.
1		S	3 16 12					First phases intermixed with trailers of previous quake.
		L?	3 25 54					
		i	3 28 48					
		eL	3 29 24					
		M	3 31 54		*4,000			
		iL	3 36 30					
		iL	3 38 48					
		iL	3 44 42					
		M	3 54 48		*3,400			
		iL	3 55 36					
		iL	3 57 18					
		iL	4 01 30					
		iL	4 09 06					
		iL	4 13 12					
		iL	4 21 24					F lost in microseisms.
5								Heavy microseisms at time of 'quake at other stations.
6		L	23 26 36					
		eL	23 30 30					
		M	23 33 12		*700			
		eL	23 38 36					F lost in microseisms.
7		L	0 41 54					
		eL	0 44 00					
		M	0 46 00		*400			F lost in microseisms.
8		L	2 03 06					
		eL	2 05 24					
		M	2 08 00		*300			F in microseisms.
17		L	12 09 42					Microseisms going on.
		M	12 16 48		*200			F in microseisms.
27		L?	21 56 06					Microseisms going on.
		M?	21 58 06		*300			
		eL?	22 19 00					F in microseisms.
31		L	23 48 48					Small microseisms going on.
		L	23 56 54					
		M			*200			
Feb. 1		L	0 01 48					F in microseisms.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant..18 T_0. Pillar deviation, 1 mm., swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Jan. 1		P	1 47 32				9,220	F lost in next 'quake.
		S	1 57 53					
		L	2 11 50					
		M	2 41 05		*1,400			
1		P	3 11 00				1,310	
		S	3 13 19					
		L	3 17 17					
		M	3 22 44		*6,300			
		F	6 05 23					
			VERTICAL.		A_z			
		P	*3 11 12*	*2–3*			*1,040*	*L?, F?*
		S	*3 13 04*	*4–6*				
		M	*3 26 00*	*24*	*143*			
6		L	20 39 59					
		M	20 43 25		*200			
		F	20 51 17					
6		P	22 47 55				4,120	
		S	22 53 49					
		L	23 03 40					
		M	23 16 27		*2,000			
7		F	0 17 28					
			VERTICAL.		A_z			
		L	*23 06 00*	*24*				
		M	*23 11 00*	*20*	*3*			
7		P	0 44 28				1,710	
		S	0 47 25					
		L	0 51 21					
		M	0 59 13		*300			
		F	1 15 57					
8		P	2 17 08					
		L	2 21 36					
		M	2 24 34		*400			
		F	2 41 55					
17		P	12 09 07				660	
		L	12 10 35					
		M	12 12 04		*2,400			
		F	12 22 53					
			VERTICAL.		A_z			
		P	*12 09 00*	*2*				*L?, F?.*
		M	*12 12 30*	*10*	*143*			
27		L	21 50 47					
		M	21 58 14		*200			
		F	22 23 01					
31		P	23 45 26	3			615	
		L	23 46 55					
		M	23 47 35		*1,000			
Feb. 1		F	0 03 47					
			VERTICAL.		A_z			
		P	*23 45 12*	*3*			*600*	
		L	*23 46 34*	*8*				
		M	*23 47 20*	*20*	*6*			
		F	*0 00 00*					

SEISMOLOGICAL DISPATCHES.[1]

No reports for January, 1919.

[1] Reported by the organization indicated and collected by the seismological department of Georgetown University, Washington, D. C.

Chart I. Hydrographs of Several Principal Rivers, January, 1919.

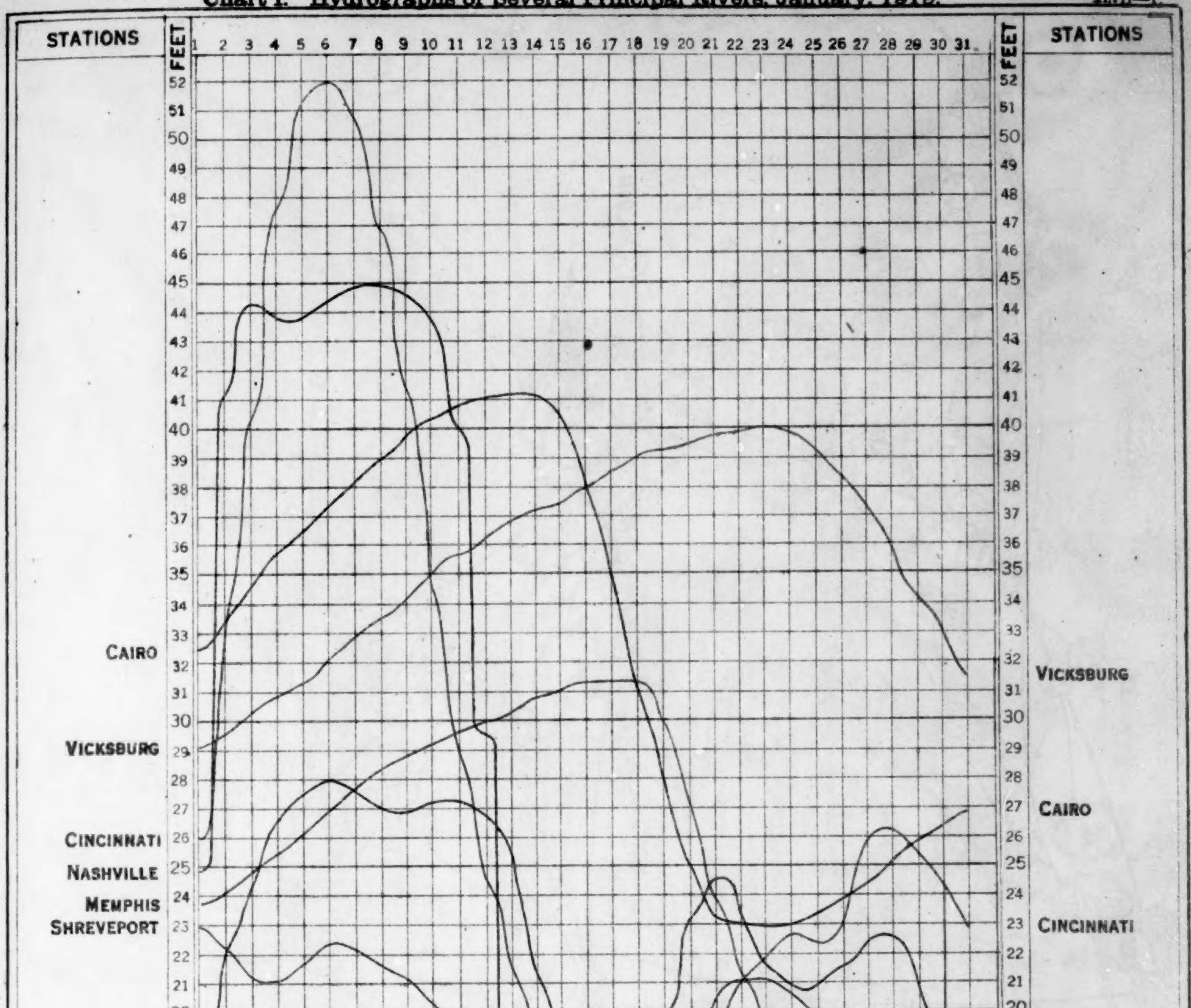


Chart II. Tracks of Centers of High Areas, January, 1919.
(Plotted by Charles A. Donnel.)

Chart III. Tracks of Centers of Low Areas, January, 1919.
(Plotted by Charles A. Donnel.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, January, 1919.

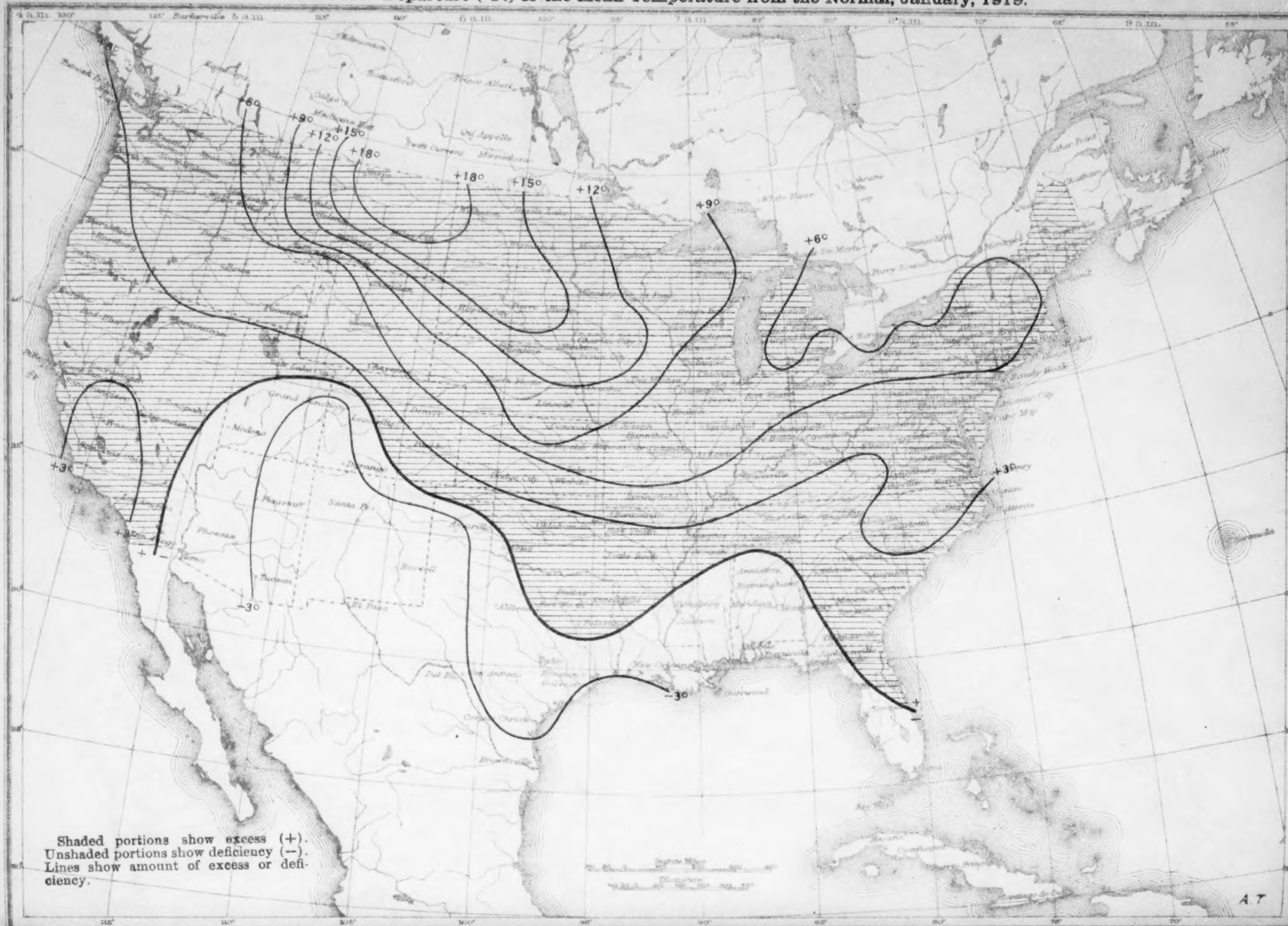


Chart V. Total Precipitation, Inches, January, 1919.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, January, 1919.

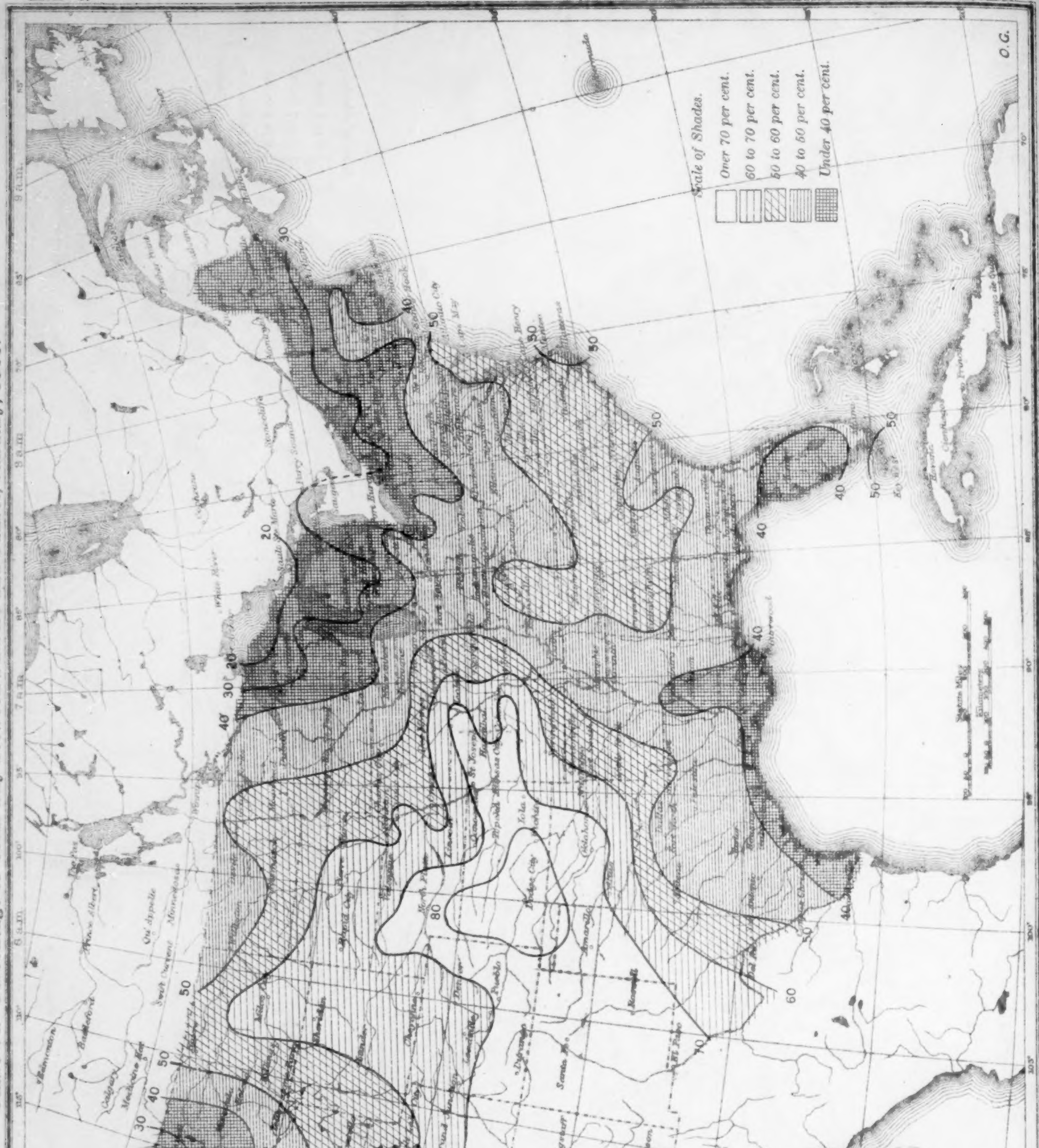


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, January, 1919.

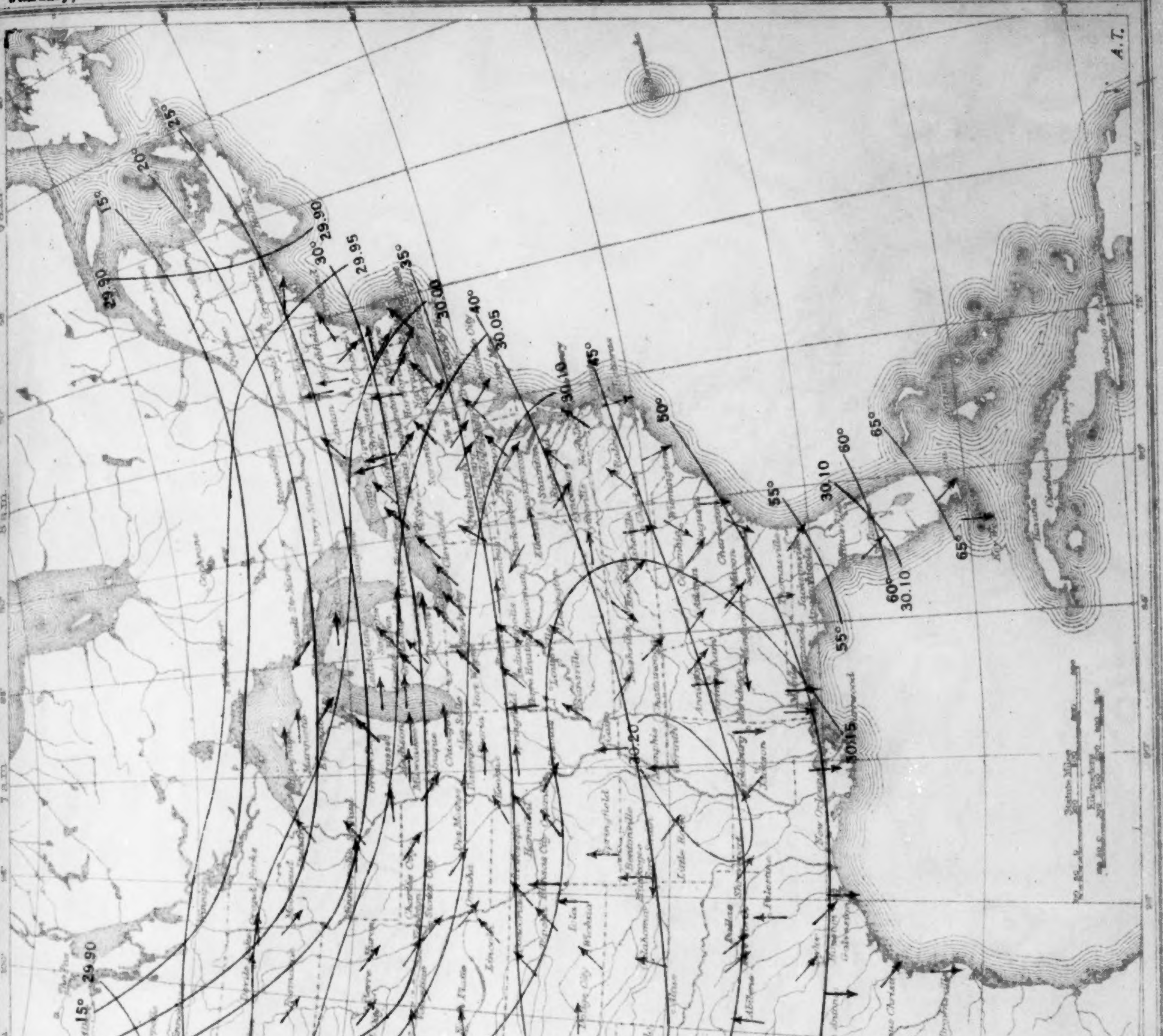


Chart VIII. Total Snowfall, Inches, January, 1919.

Chart IX. Meteorological Data for North Atlantic Ocean, January, 1919.

Chart IX. Meteorological Data for North Atlantic Ocean, January, 1919.

(Plotted by F. A. Young.)

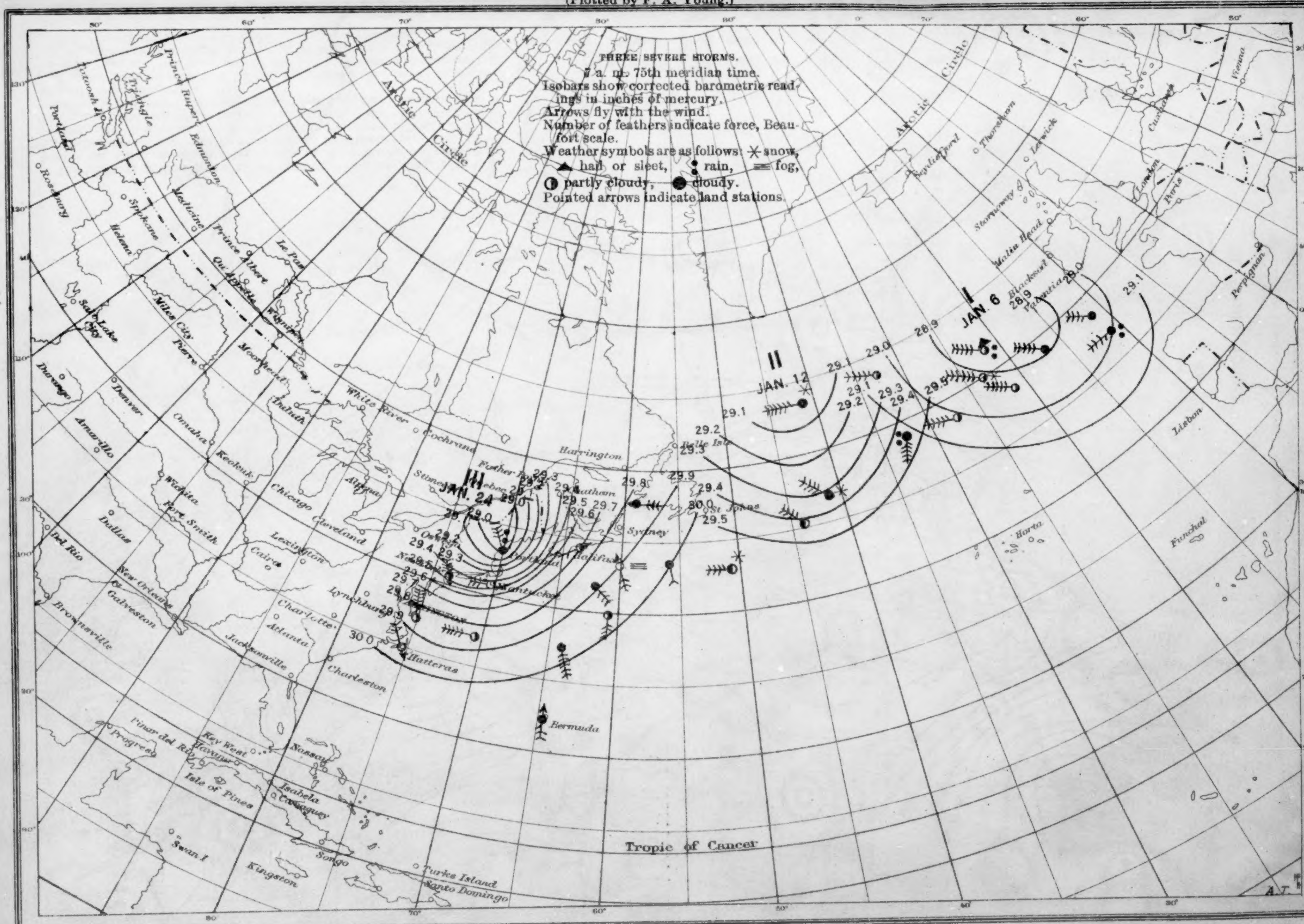
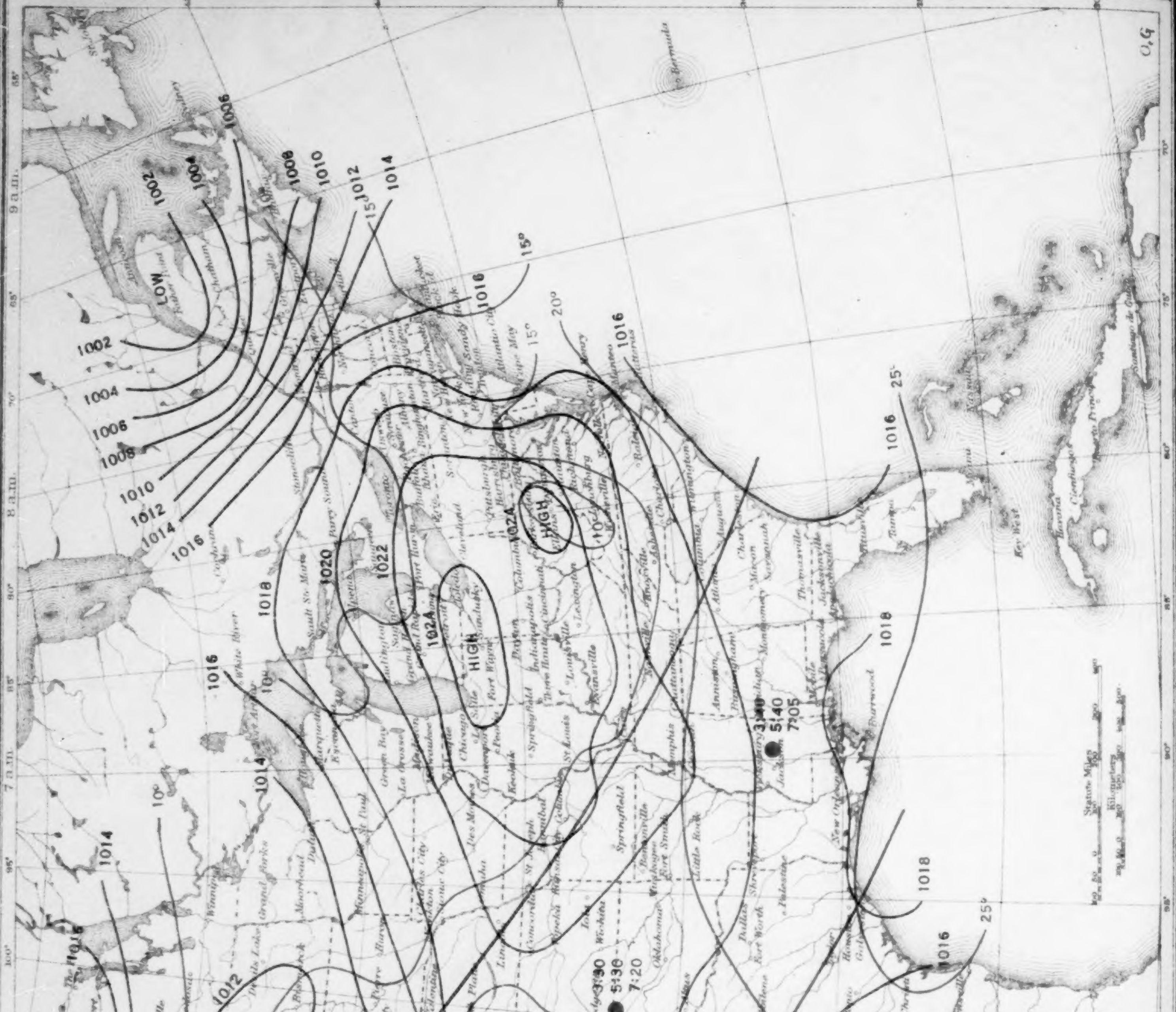


Chart X. General Circumstances of Eclipse and Meteorological Conditions at 7 a. m., June 8, 1918.



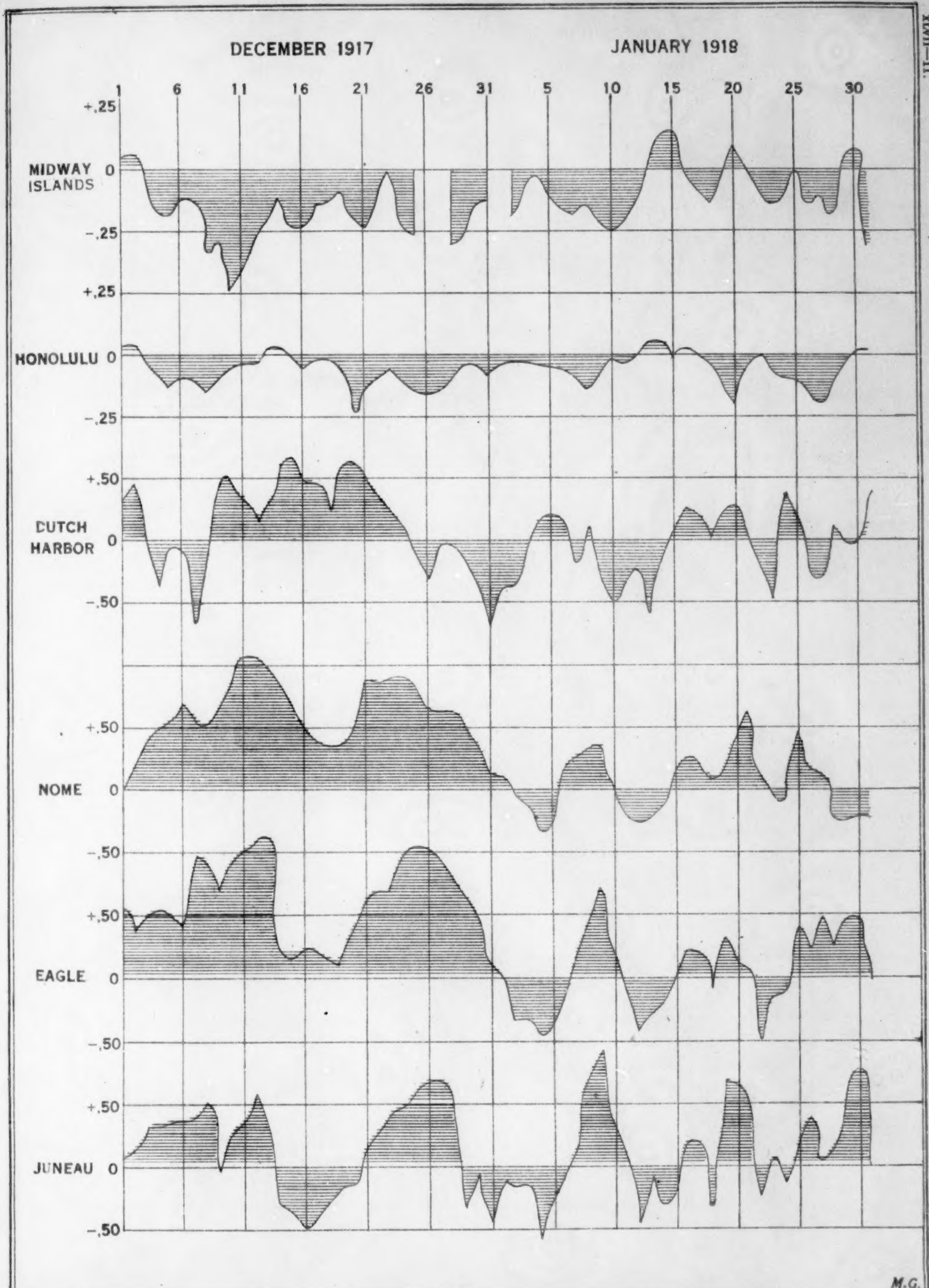
The position of the shadow at intervals of 10 minutes, beginning with 2:50 p. m., 120th meridian time, is indicated by the row of red circles extending across the country from Oregon to Mississippi.

Beginning at the top, the figures near the red circles indicate, respectively, the 120th meridian time of totality, the local standard time of totality (if different from that of the 120th meridian), and the time of sunset (local standard).

The red lines on each side of and approximately parallel to the row of red circles indicate the limits of the belt of 90 per cent obscuration.

Isobars, in millibars, and isotherms, in degrees centigrade, are indicated, respectively, by the numbered black and red lines.

E. H. B. XI. Pressure abnormalities during December, 1917, and January, 1918, for Midway Islands, Honolulu, and Alaskan stations.



E. H. B. XII. Pressure abnormalities during December, 1918, and January, 1919, for Midway Islands, Honolulu, and Alaskan stations.